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EDITORIAL NOTE TO VOLUME V, NUMBER 1

THIS number of Forestry contains two articles which it is hoped will begin a series.

Dr. J. D. Sutherland has suggested that biographical memoirs on notable men who have contributed to British Forestry would be of interest. He contributes a memoir on Archibald Menzies, the botanical explorer, who discovered some of our most important trees, including Sitka spruce.

The outstanding post-war feature of British silviculture has been the greatly increased use of Sitka spruce. Sir R. L. Robinson has suggested that available knowledge regarding this species should be published in a series of articles. Mr. A. D. Hopkinson, as a result of his recent visit, contributes the first article of this series—'Sitka Spruce and Other Conifers on the Queen Charlotte Islands'. Further articles will deal with the species in Great Britain, its establishment, growth and production, and timber.

EDITORIAL NOTE TO VOLUME V, NUMBER 2

THE series of articles on Sitka Spruce, begun in Volume V, No. 1, is continued in this number by three articles. Further articles will appear in future issues. The series of biographical memoirs is also continued. In this number the first two of a set of five articles on Wood Preservation are published. These contributions, by members of the Forest Products Research Laboratory, were read at the British Association Meeting, 1931, and will be welcomed by members as stating the present position of this important subject.

Owing to the number of articles to be published, the space allotted to reviews and notices has had to be reduced temporarily.

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CONTENTS

Number 1

An Address to the Society of Foresters. By J. D. SUTHERLAND . . 1
Archibald Menzies, 1754–1842. By J. D. SUTHERLAND . . . 5
Notes on the Sitka Spruce and other Conifers on the Queen Charlotte Islands. By A. D. HOPKINSON 9
The Place of Douglas Fir in Scottish Forestry. By FRANK SCOTT. . 14
Studies in the Biology of *Xylonomus brachylabris* Kr., and *X. irrigator* F., Parasites of the Larch Longhorn Beetle, *Tetropium gabrieli* Weise. By R. N. CHRYSTAL and E. R. SKINNER. (With Plates I–II) . . 21
Squirrels and Forestry. By A. D. MIDDLETON 34
The Relationship between Frost Damage and Larch Canker. By W. R. DAY. (With Plates III–IV) 41
The Dry Weight of Wood. By R. A. G. KNIGHT 57
The Forests of Sweden. By ERIK THORELL 66
Society and Other News:

REVIEWS

Handbuch der Freien Durchforstung mit Beiträgen zum forstlichen Versuchswesen (DR. CARL ROBERT HECK). By W. H. GUILLEBAUD . 75
Die Stoffbewegungen in der Pflanze (E. MÜNCH). By R. N. ALDRICH-BLAKE 78
The Plasticity of the Root System of Corsican pine in early Life (R. N. ALDRICH-BLAKE). By PROF. J. H. PRIESTLEY. 80
Studies in the Physiology of Cambial Activity (PRIESTLEY). By R. N. ALDRICH-BLAKE 81
The Rooting of Woody Cuttings considered from the standpoint of Anatomy (SLEDGE). By R. N. ALDRICH-BLAKE 83
Some Observations on Cambial Activity and Seasonal Starch Content in Sycamore, *Acer Pseudo-platanus* (COCKERHAM). By R. N. ALDRICH-BLAKE 84
Observations on the Parasites of the Pine-Shoot Moth, *Rhyacionia* (*Evetria*) *buoliana* Schiff (W. H. THORPE). By R. N. CHRYSTAL . 84
Effect of Time of Felling upon the Durability of Timber (E. Gäumann). By W. P. K. FINDLAY 85
The Use of Home Grown Larch Poles for Transmission Lines (Forest Products Research Laboratory). By J. T. SMITH 88
Our Catkin-bearing Plants (H. GILBERT-CARTER). By J. BURTT DAVY . 89
Révision du Genre Abies (H. GAUSSEN and TH. VIGUIE). By J. BURTT DAVY . 89
Une Nouvelle Espèce de Sapin, *Abies pardei* (Gaussen). By J. BURTT DAVY . 90
A travers les Forêts de pinsapo d'Andalousie (A. BARBEY). By the EDITOR . 90

NOTICES

The Death-Watch Beetle 91
Empire Timbers from Home and Overseas for building and structural Purposes (MAJOR J. R. COSGROVE) 91

Preliminary report on the creosoting of Douglas fir Sleepers (J. BRYAN) . 91
Enquête internationale sur la standardisation de la Mesure du Bois sur les différents Modes de Vente du Bois 92

Number 2

Use of Sitka Spruce in British Afforestation. By SIR ROY L. ROBINSON . 93
Sitka Spruce—On poor Soils and at high Elevations. By SIR JOHN STIRLING-MAXWELL, Bart 96
Sitka Spruce in Great Britain—Its Growth, Production, and Thinning. By JAMES MACDONALD 100
A Commercial Reafforestation Project. By ELLWOOD WILSON . . 108
Notes on the Biology of the Large Elm Bark-Beetle, *Scolytus destructor* Ol. By RONALD C. FISHER. (With Plate V.) 120
An Instance of 'Damping-Off' Retarded by the Use of Basic Slag. By W. G. GRAY 132
Wood Preservation: An Introduction. By R. S. PEARSON . . . 136
The Toxicity of Preservatives against Wood-destroying Fungi. By K. ST. G. CARTWRIGHT 138
Notes on the Carpathian *Urwald*. By W. L. TAYLOR 148
David Douglas. By J. M. MURRAY 154
The Forestry Sub-section of the B. A. Centenary Meeting, London, 1931 159
Society and Other News 160

REVIEWS

An Outline of Forest Pathology (E. E. HUBERT). By W. R. DAY . . 164
Unsere Kenntniss von Forstsaatgut (W. SCHMIDT). By R. N. A.-BLAKE 166
Seeding and Planting in the Practice of Forestry (J. W. TOUMEY, second edition). By the EDITOR 166
The Grey Squirrel (A. D. MIDDLETON). By the EDITOR . . . 167
Welsh Timber Trees (H. A. HYDE). By the EDITOR 167
Forest Gardens (Forestry Commission Bulletin No. 12). By T. THOMSON 168
The Effect of Progressive Decay by *Trametes serialis* Fr. on the Mechanical Strength of the Wood of Sitka Spruce. (Forest Products Res. Lab., Bulletin 11). By W. R. DAY 169

NOTICES

The Training of Candidates and Probationers for Appointment as Forest Officers in the Government Service (H.M.S.O.) . . . 169
Imperial Bureau of Soil Science Publications 170
Types of Humus Layer in the Forests of North-eastern United States. By L. G. ROMELL and S. O. HEIBERG 171
Empire Forestry Handbook, 1931 172

AN ADDRESS TO THE SOCIETY OF FORESTERS[1]

BY J. D. SUTHERLAND

I HAVE had the privilege of acting as your President for the last two years as well as taking some of the responsibility for our first President, Mr. Robinson, when he had to leave for Australia to attend the Imperial Forestry Conference. The experience of these years has been a pleasure and the labour has been lightened by the ever-available assistance of our honorary secretary, Mr. R. Angus Galloway, and the cordial support of every member of Council. I feel that the Society has now firmly established itself at home and abroad and that our Journal *Forestry* has taken its place as a publication of recognized authority. For the excellence of *Forestry* we have to thank the contributors, but we are especially indebted to Dr. H. M. Steven, our Editor, for a great amount of work and very generous service. As is natural, our activities during these years have been concentrated in constructive effort. There are older associations with traditions of credit and of honour in the sphere of silviculture, but it must be recognized that no profession is complete without an organization which can protect the interests of its members, and at the same time create a high standard of character, of thought, and of conduct. Medicine and law, I only quote two examples, founded their respective associations long ago, with the result that the codes laid down by them have enhanced the repute and the standing of these two great professions.

It is safe to assert that the growing of timber is accepted all over the world as necessary, and we know that the profession of technical forester is a serious and responsible vocation, and this realization is confirmed after recent experiences of planting in Britain. For this reason alone we must stand together and share our problems and anxieties in conference. I am not endeavouring to advocate the need of our combination, I believe this is now accepted, but would urge a still closer union not only among ourselves but with those engaged in the sciences that are allied to our subject. Contact with these branches of science is of the utmost importance, and it is by interesting the botanist, the geologist, the soil scientist and the wood technologist, that we may hope to advance most securely.

Recently a Committee has been asked to report upon the educational systems of forestry in this country, and at one time I thought that we should offer to state the views of the Society to this Committee. I desisted from action, however, pending this meeting, and it is for you to say to-day whether we should press for a hearing. The educational problem is complicated in respect that men have to be trained for both colonial and home service. Up to a point aspirants in either can well work together, but as the management of forests in different parts of the Empire, and in different stages of development, calls for

[1] Delivered at the Annual Meeting, 1931.

different knowledge, it seems likely that under the present organizations there may be some wastage of time and of effort. Again in this connexion, it may be asked whether the Universities are keeping pace with the new problems of the time. There also appears to be a distinct diversity in the teaching at these centres and I feel that in none of them is there sufficient opportunity for the student to become acquainted with the 'living' forest, and that a closer alliance between science and practice should be encouraged. Perhaps the ideal school might in the end be a national college, situated in or near large forests after the model of the French Institution at Nancy.

For the subordinate forester staff the two training-schools seem meantime to supply the education and working experience required. The trainees issuing from these schools are sufficiently equipped to undertake the management of planting at a comparatively early age. The past educational record is good in this direction, but it may not be sufficient for the management of plantations after they are established or for the exploitation of the crop which is coming.

During the past eleven years over 150,000 acres have been translated from other uses to that of forestry. The direct local effect of the change is apparent at once in increased employment, in the migration and resettlement of people, and these changes are at present accepted as a natural consequence of the operations. But this national undertaking envisaging forests covering a million acres or more will introduce new problems in a wider field. The economics of the future have to be anticipated. When the forests are capable of yielding crops the utilization of them, especially the marketing of the immature crops, must be tackled, and new uses will have to be found for this timber and further settlements of people will have to be created for the influx of labour. Present-day methods of exploitation will cease, and mills and factories with improved plant and machinery will have to appear. Here there is a fresh subject for the teacher of forestry and a new field for the economist and for those interested in the distribution and reorganization of labour and industry. In the search for new outlets for timber and the proper treatment of it, we are now fortunately able to trust to the Forest Products Research Laboratory, the institution of which under the present Chief, your new President, Mr. Pearson, has done remarkable service and will do more to fortify the resuscitation of our home timber trade by safe and promising routes.

The planting of some thousands of acres annually upon unknown soils and undiscovered conditions was a complete innovation, and the raising of important stocks of seedlings and of plants was an undertaking new in this country even to the then existing nursery trade. In relation to the hitherto unknown conditions to which I have referred, it seems to me that we should make a closer study of meteorology. Until now this science has never been properly correlated to silviculture, and here there is further opportunity for the investigator. Some work has been done in Japan by Y. Kitamaru on this subject, and investigations have also been begun by Mr. W. R. Day at Oxford.

In the classification of ground for planting and in the selection of species, a definite advance can be claimed. The meaning and use of types of vegetation

and field methods of soil survey have improved and in this connexion forestry literature has been enriched by Cajander's *Theory of Forest Types*. The outstanding work upon Forest Soils by Professor Hesselmann and his associates in Sweden has demonstrated the importance of nitrification in woodland soils, and we now know that regeneration of Scots pine is impossible where that process is not taking place. Cultural methods to improve nitrification have been investigated by Hesselmann, and the application of these must result in removing the disappointments of the past in the regeneration of our indigenous pine. In Sweden, Finland, and elsewhere, and I am glad to record in Britain as well, peat soils have not been neglected. Upon the purely scientific side Malmström in Sweden has provided us with an exhaustive study of the origin and development of peat. Through research at home we have now a better conception of the problem. It is certainly possible to clearly distinguish the difference between good and bad peat, i.e. plantable and unplantable, and we know that the micro-organisms which are helpful to tree development can be developed and increased in the peat when suitable conditions are created. In this investigation valuable contributions have been made by Dr. E. V. Laing and by Mr. G. K. Fraser at Aberdeen University, and as well by the research department of the Forestry Commission. Researchers have been greatly assisted in their peat investigation by a purely private enterprise upon the part of Sir John Stirling Maxwell, commenced thirty years ago and conducted under difficulties which would deter any but a courageous pioneer. Through the treatment of the plantations at Corrour research has been simplified and mistakes have been avoided. These suggestive operations have encouraged the belief that in the peat mosses we can, by the use of intensive drainage, planting on upturned turves, and by the application of chemical substances, assure the establishment of plantations over regions which gave little prospect of tree life. Now various types of planting on turves are the subject of many experiments. As information and experience are collected we can hope for greater success, and no aspect of afforestation deserves more steadfast attention. The conversion of the waste peat mosses, which cover so vast an area, into productive forest will be an achievement of the greatest importance.

The knowledge of the fungi of forest soils has been greatly increased by the work of Elias Melin of Stockholm, whereby we now may believe that mycorrhiza do not fix the nitrogen of the air but are occupied with the conversion of nitrogen which is already in the soil, but which is not in a form available to the tree. A further interesting discovery by Melin is the close connexion between mushrooms and mycorrhiza, that the former play a very important part in the life of the forest, and that many can be associated with particular tree species. Research on these woodland fungi is, I am glad to say, being actively prosecuted in this country in particular by Drs. E. V. Laing and M. C. Rayner. A further feature of research is the increased attention which has been paid to the root development of the tree. In Britain this study has been mainly confined to root development in trees growing in peat, but Mr. Aldrich Blake has aided us by his investigation of the root system of the Corsican pine. Both on the

Continent and in America we have had records on similar lines on the Scots pine and on Douglas fir and other species which I believe have been helpful. Experiments in root pruning and manuring both in the forest and the nursery are proceeding and may bear fruit. There is still the mineral food of our conifers to investigate. In mycology there has been an abundance of literature and several discoveries can be claimed during the last eleven years to which Dr. Malcolm Wilson and Mr. W. R. Day have contributed.

Altogether we can look back upon the period of State Forestry in Britain with satisfaction. The technique has undoubtedly improved since afforestation became a national undertaking, and encouragement has come from our foreign contemporaries who have crossed the seas to inspect and to collect information. I quote in conclusion a communication from one of them: 'I was particularly impressed with the large measure of success shown in most of the plantations. It is an inspiration to see such good work and I hope we can get things going in the same way across the Atlantic before many moons.'

Many similar tributes have been received from the Continent, from Japan, and our associates in the Dominions. They are gratifying, but for the good results obtained we have to claim a large degree of credit for the forest officers and the foresters who have conducted the work in the field with exceptional skill and discretion. The share taken in all this forward movement by our fellow members is remarkable and I feel assured that as the years pass this share will increase.

ARCHIBALD MENZIES

1754–1842

BY J. D. SUTHERLAND

WE have no long roll of distinguished foresters but we can claim some remarkable men, and many who have done notable service. Archibald Menzies, although a botanist and not a forester, is one whose name will be for ever associated with forestry. The objective of foresters until recently was naturally overseas, but the new Forest Service in Britain may alter this outlook. A friend, versatile in many subjects, asked last month if the Sitka spruce was a good tree. This inquiry surprised me, because over many years he has never evinced the slightest interest in silviculture. Then I found that he was a great grand-nephew of Archibald Menzies, to whom we owe not only this spruce but many other trees and shrubs and plants. One afternoon later I saw the watch and spectacles and other personal possessions of the explorer, all displayed in a curio-table made of the wood of the first Araucaria grown at Kew from seed brought over here by Menzies, and named as hundreds of other growing things have been similarly named after him. Among these treasures was a holograph letter written to Archibald Menzies from London on 22 February 1791, by Sir Joseph Banks, later President of the Royal Society, in the following terms:

'The business on which you are employed being of an extensive nature as it includes an investigation of the whole of the natural history of the countries you are to visit, as well as an enquiry into the present state and comparative degree of civilisation of the inhabitants you will meet with, the utmost degree of diligence and perseverence on your part will be necessary to enable you to do justice to your employers, and gain credit to yourself. The following instructions you will consider as a guide to the outline of your conduct, but as many particulars will doubtless occur in the investigation of unknown countries, that are not noticed in them, all such are left to your discretion and good sense, and you are hereby directed to act in them as you judge most likely to promote the interest of science, and contribute to the increase of human knowledge.

'In all places where the ship in which you are embarked shall touch, and the commander shall make a sufficient stay, you are to pay a particular regard to the nature of the soil, and to note down its quality, whether clay, sand, gravel, loam, etc. etc. and how it is circumstanced in regard to water, you are to remark particularly the size of the trees that grow upon it, whether they stand in thick close groves, or separate and distant from each other. You are to consider also, as far as you are enabled to do by the productions, the probable climate, and whether, should it at any time hereafter be deemed expedient to send out Settlers from England, the grains, pulse and fruits cultivated in Europe are likely to thrive, and if not, what kind of produce would in your opinion be the most suitable.

'As far as you find yourself able, you are to enumerate all the trees, shrubs, plants,

grasses, ferns and mosses you shall meet with in each country you visit, by their scientific names, as well as those used in the language of the natives, noting particularly the places where each is found, especially those that are new or particularly curious. You are also to dry specimens of all such as you shall judge worthy of being brought home, particularly those of which you shall procure either living plants or seeds, in order that the persons who are employed in examining the plants you furnish to His Majesty's Gardens at Kew, may be assisted in ascertaining their names and qualities.

'Whenever you meet with ripe seeds of plants, you are carefully to collect them, and having dried them properly, to put them up in paper packages, writing on the outside, or in a corresponding list, such particulars relative to the soil and climate where each was found and the mode of culture in your opinion likely to succeed with it, as you may think necessary to be communicated to His Majesty's Gardeners, and you are to forward these packages directed to me for His Majesty's use by every convenient opportunity that shall occur, dividing them, for safety's sake, into duplicates, as often as you shall judge needful.

'When you meet with curious or valuable plants which you do not think likely to be propagated from seeds in His Majesty's Garden, you are to dig up proper specimens of them, plant them in the glass frame provided for that purpose, and use your utmost endeavour to preserve them alive till your return, and you are to consider every one of them, as well as all seeds of plants which you shall collect during the voyage, as wholly and entirely the property of His Majesty, and on no account whatever to part with any of them or any cuttings, slips or parts of any of them, for any purpose whatever but for His Majesty's use.

'As soon as you shall have provided yourself with living plants, and planted them in the glass frame before-mentioned, you are at all times when the Ship shall be watered to acquaint the Commanding Officer what quantity of water you judge necessary for their support and preservation by the week or month, in order that he may be enabled to make a competent provision of that Article for their future maintenance and nourishment.

'In all your excursions on shore, you are to examine with care and attention the beds of brooks and torrents, the steep sides of cliffs and all other places where the interior strata of the earth are laid bare by water or otherwise, to remark the nature of the earth and stones of which they are composed, and if among them you discover ores, or metals, or any mineral substances which bear a resemblance to such things or any beds of coal, limestone or other matters, likely in your opinion to prove useful to mankind, you are to collect and preserve specimens of them carefully, noting the exact spot on which each was found, and you are also to examine the pebbles and sand brought down by the rivers and brooks from the inland country, and to collect and bring home samples of such as you suspect to contain mineral substances even though so minute as not to be discoverable but by a microscope.

'At each place where you land, you are to inform yourself, as well as you are able, what sort of beasts, birds and fishes likely to prove useful, either for food or in commerce, are to be found; and pay particular attention to the various ways of catching them in traps or other ways used by the natives; you are to pay particular attention to every part of the natural history of the Sea Otter, and to learn all you are able concerning the wild sheep said to be found in the inland countries, and, if in your power, to procure a skin of one of them for your employers; you are also to note particularly all places where whales or seals are found in abundance.

'At all places where a friendly intercourse with the natives is established, you are to

make diligent enquiry into their manners, customs, language and religion, and to obtain all the information in your power concerning their manufactures, particularly the art of dyeing in which Savages have been frequently found to excel and if any part of their conduct, civil or religious, should appear to you so unreasonable as not to be likely to meet with credit when related in Europe, you are, if you can do it with safety and propriety, to make yourself an eye-witness of it, in order that the fact of its existence may be established on as firm a basis as the nature of the enquiry will permit.

'You are to keep a regular journal of all occurrences that happen in the execution of the several duties you are entrusted to perform, and enter in it all the observations you shall make on every subject you are employed to investigate; which Journal, together with a compleat collection of specimens of the animals, vegetables and minerals you shall have obtained, as well as such curious articles of the cloths, arms, implements and manufactures of the Indians as you shall deem worthy of particular notice, you are on your return to deliver to His Majesty's Secretary of State for the Home Department, or to such person as he shall appoint to receive them from you.'

This communication is quoted verbatim because it throws light upon the pioneer spirit of the time and because it is evidence of the comprehensive character of the investigations entrusted to Menzies. Besides it is an example of lucid direction to which we are not now over prone.

Archibald Menzies was born in Perthshire at Weem on 15 March 1754, and from the County School he passed to the Royal Botanic Gardens in Edinburgh, to which he afterwards bequeathed his large botanical collections. His unusual capacity was soon recognized there, and later he graduated in medicine at the University. His first botanical work was achieved on foot among the Scottish Highlands, but joining the Navy as surgeon he sailed in 1786 in the ship *Prince of Wales* for the north-western coast of America. On this voyage he accomplished several dangerous mountaineering feats in the Islands of Hawaii and gained the confidence of the native chiefs. Returning three years later with many varieties of seeds and plants and reliable geological surveys, he was engaged by Sir Joseph Banks as above explained and left England in 1791 in the *Discovery*, which was in command of Captain George Vancouver. The *Discovery* returned to England in October 1795. Menzies then brought with him a large and valuable collection of the flora of the regions visited. In addition to *Picea sitchensis*, Menzies has the credit for the discovery of *Pinus contorta*, *P. monticola*, *Sequoia sempervirens*, *Thuya plicata*, and as well many hardwoods. His diaries do not contain lengthy descriptions of scenery or any very lively passages of his experiences, but in so far as they relate to the objects of his quest, his writings are clearly those of an accurate observer. Menzies ultimately retired from the Navy, but when this step was taken he continued his botanical studies, became doyen of the Linnean Society, and died at the age of 88 on 15 February 1842. My friend, Charles D. Geddies, has given me such authority as may seem necessary in making this record of his distinguished forbear.

The Sitka spruce did not come into favour until long after the death of Menzies. A quantity of seed was brought into England in 1831 and the large

Sitka spruce at Keillour was planted about four years later, but the old tree at Castle Menzies near Archibald Menzies' birthplace would seem to be about ten years younger. The plantation at Durris, Kincardineshire, was the first plantation of the tree in Britain and it unfortunately has been blown down. Since 1919 *Picea sitchensis* has gained very marked consideration and it is now extensively used in the State Forests of this country.

NOTES ON THE SITKA SPRUCE AND OTHER CONIFERS ON THE QUEEN CHARLOTTE ISLANDS

BY A. D. HOPKINSON

THE Queen Charlotte Islands lie about sixty miles off the west coast of British Columbia between approximately the same latitudes as London and North Yorkshire. They comprise a chain of one hundred and fifty or more islands large and small and may be described as mountainous, although the altitude is never greater than about 4,000 feet above sea level.

The climate is equable and maritime, the Japanese Stream which flows near the western shores being comparable in its effect to that of the Gulf Stream on the British Isles. The rainfall varies considerably, but the average for the islands may be put at 80–90 inches per annum, although the data available are not extensive. Approximately only 19 per cent of this falls during the summer months of May to September, the remainder falling during the rest of the year, hence the winters are normally very wet and the summers drier, although still with an appreciable rainfall each month. Moderate temperatures are experienced both in winter and summer. The following table gives the average mean monthly temperature for Masset (north end of Graham Island) and for comparative purposes the estimated mean monthly temperatures at 800 feet elevation at the following British Stations:

Bellingham (Northumberland), Newcastleton (Roxburghshire), Glenbranter (Argyll), Achnashellach (Ross and Cromarty), Bettwys-y-Coed (Carnarvon), Carrick-on-Suir (Waterford),

Month.	*Masset.*	*Bellingham.*	*Newcastleton.*	*Glenbranter.*	*Achnashellach.*	*Bettwys-y-Coed.*	*Carrick-on-Suir.*
January . .	35	35	35	36	35	38	38
February . .	36	36	36	36	35	38	39
March . .	39	38	38	38	37	40	41
April . . .	42	42	42	43	41	44	45
May . . .	47	48	48	49	46	49	50
June . . .	53	54	54	54	51	54	55
July . . .	57	56	56	55	53	57	57
August . .	58	56	56	54	53	56	57
September .	53	52	52	52	50	53	53
October . .	47	45	45	45	44	46	47
November .	40	40	40	40	36	41	42
December .	38	37	37	37	36	39	39
Year . .	45	45	45	45	43	46	47

In mean monthly temperature, therefore, the Queen Charlotte Islands closely resemble north-west England and south-west Scotland.

The geology is complicated and somewhat obscure, but it would appear that the older igneous and metamorphic rocks have been largely covered with sedimentary deposits such as conglomerates, shales, and sandstones. Glacial soils and subsoils are often found and these are noticeably impervious. The lower slopes of the mountains appear to be covered, partially at least, with a somewhat sandy soil often of considerable depth, and it is on such sites that the finest growth of Sitka spruce is found.

On the slopes of the mountains the organic matter is composed almost entirely of decayed wood and tree foliage together with the decomposed remains of the remaining forest vegetation. On the flat swampy country (muskeg) which lies to the north of Graham Island there are considerable formations of peat up to 6 feet in depth. This peat has been caused by lack of quick drainage due to an impervious subsoil—a frequent cause of peat formation in this country—but the Queen Charlotte Islands' peat has been derived from different species of plants, although the latter include species of *Ericaceae* and *Sphagnum*. The typical muskeg, whether covered with a poor growth of *Thuya plicata* or free from tree growth, is not comparable to the typical high peat moors of Great Britain, but more nearly approaches a lowland swamp in character. There are no *Calluna* or *Molinia* peats in the Queen Charlotte Islands, but *Sphagnum* is a constituent of the typical muskeg vegetation, although an unimportant one.

The vegetation of the Queen Charlotte Islands shows everywhere a luxuriant growth both of trees and other plants. On every hand there is abundant evidence of a moist climate, such as the ferns and mosses which abound in the forests. Taking first the plants other than trees, the prevalence of berry-bearing species such as huckleberry and salmonberry is very striking. There are species of *Vaccinium* and *Ribes* growing 10 feet high, rendering parts of the forest an almost impenetrable jungle. Salal is another very common plant, perhaps the most common in the forest, and elderberry luxuriates in many parts. Bracken is also found quite abundantly, even penetrating to some extent on to the muskeg country. The skunk cabbage—a remarkable plant with leaves 3 and 4 feet long—is a characteristic species of swampy conditions.

A number of plants are characteristic of both the best forest conditions and also the swamp (muskeg) country where tree growth is comparatively poor or even absent, while certain others are typical of only one or the other as will be seen from the following list.

There are three main tree species on the islands, namely Sitka spruce (*Picea sitchensis*), Red cedar (*Thuya plicata*), Western hemlock (*Tsuga heterophylla*), and these together form perhaps nine-tenths of the forests. The following species are indigenous, but are of little importance from a commercial point of view: Yellow cedar (*Chamaecyparis nootkatensis*), Lodge Pole pine (*Pinus contorta*), Alpine hemlock (*Tsuga mertensiana*), Pacific yew (*Taxus brevifolia*). The only broad-leaved tree is the Red alder (*Alnus oregona*).

Typically the forests of the Queen Charlotte Islands are composed of a mixture

Family.	Species.	Occurrence.	
		Good Forest land.	*Muskeg.*
Polypodiaceae	*Pteris aquilina* (Bracken)	Common	Local
	Other Ferns	Common	Sparse
Ericaceae	*Gaultheria shallon* (Salal)	Common	Common
	Vaccinium ovalifolium (Tall Bilberry)	Common	Absent
	Vaccinium parvifolium (Red Huckleberry)	Common	Absent
	Ledum groenlandicum (Labrador Tea)	Rare	Common
	Arctostaphylos uvaursi (Kinnikinick)	Absent	Common
	Phyllodoce glanduliflora (False Heath)	Absent	Common
	Vaccinium caespitosum (Dwarf Bilberry)	Absent	Common
Araceae	*Lysichiton Kamtschatcense* (Skunk Cabbage)	Absent	Common
Liliaceae	*Streptopus roseus* (Sessile leaved Twisted stalk)	Common	Absent
Cornaceae	*Cornus canadensis* (Bunch Berry)	Common	Common
Caprifoliaceae	*Sambucus racemosa* (Red-fruited Elder)	Common	Absent
Saxifrageaceae	*Tiarella unifoliata* (Foam Flower)	Common	Absent
Rosaceae	*Rubus parviflorus* (Thimbleberry)	Common	Absent
	Rubus spectabilis (Salmonberry)	Common	Absent
	Rubus chamaemorus (Cloudberry)	Absent	Common
	Pyrus diversifolia (Crab Apple)	Absent	Local
	Spiraea densiflora (Mountain Spiraea)	Absent	Common
Ribaceae	*Ribes lacustre* (Swamp Gooseberry)	Common	Local

of the first three species, spruce and hemlock predominating on the best sites with cedar coming in strongly, even to the exclusion of spruce and sometimes hemlock where conditions become swampy. Everywhere on the islands, except the mountain tops and certain muskeg areas, there is, or was before the interference of civilized man, dense forest, so dense in fact that it can fairly be described as a jungle which can only be traversed slowly and laboriously. The traveller is faced with masses of fallen timber in all stages of decay, dense natural regeneration, and a luxuriant vegetation of plants such as salal, thimbleberry, devil's club, &c., 6 to 10 feet in height. Tree growth extends right to the high-tide mark, and on the sandy shore north of Tlell where the sea is receding Sitka spruce colonize the sand as soon as it is raised above the tide level. Thus it is not remarkable that agriculture has made but little progress, as practically every field has to be wrested from the forest at great labour and expense.

The exploration of the islands is far from complete, and little is known as to the effect of altitude on the development of the principal forest species. It is, however, known that Sitka spruce grow well up to an elevation of 1,500 feet, which, considering the moderate height of the mountains, is relatively high. Again, but little is known as to the effect of wind on the western seaboard, but from what scanty information is available it would seem probable that good stands are confined to sheltered valleys, and that the westerly winds have a considerable effect in stunting growth. It must be remembered, however, that a great extent of the sea coast, especially on the east of the islands, is land-locked and not directly exposed to sea winds.

The majority of the forests may be classified as uneven-aged climax type. Fire plays but a comparatively unimportant part in the history of the forests, and this is doubtless due to the wet climate. Fires have occurred, however, and may occur again especially on the muskeg country in the north and north-east of Graham Island. Perhaps it is due to lack of fires that the Lodge Pole pine has made such poor headway as compared with its development on parts of the mainland of British Columbia.

In spite of the density of the forest the average yield of timber per acre is low owing to reductions caused by poor stands in swampy areas, and probably does not exceed three to four thousand cubic feet per acre, although there are stands containing two and three times this volume.

Sitka spruce, although only forming from 20 to about 40 per cent of the volume of the forests, is the principal commercial species. It is capable of growing to a great size, and specimens 6 feet in diameter at breast height are not uncommon. Such trees are generally from 200 to 250 feet in height, but even larger dimensions are on record, and take approximately 600 years to reach maturity, at which age many are still quite sound. Good stands can be seen a little over 200 feet in height, and with a breast-height diameter of 2 feet 6 inches at an age of 300 years. In such stands the Sitka spruce has good silvicultural characteristics, being straight, clean, and cylindrical.

Natural regeneration is nearly everywhere abundant, and this species shows a marked preference for germinating on decaying wood. Furthermore it is capable of developing normally for at least the first thirty or forty years of its life without any contact with the mineral soil whatsoever. It appears doubtful whether it could reach maturity without such a contact, but it is evident that throughout life it is much more dependent for nourishment upon the organic than upon the inorganic soil horizons.

Sitka spruce is typically a flat-rooted tree, but the depths to which its roots penetrate depend upon the nature of the subsoil. On a sandy loam they reach a considerable depth, but on impervious clay soils trees over 200 feet in height do not send their roots more than 18 inches into the mineral soil and the bulk of the great system is developed in the superficial organic layer. Natural seedlings show the same characteristic as young plants in this country of sending out long strings of roots just under the surface of the organic layer.

This species appears to be able to resist sea winds, and although the trees on the seaboard are mostly comparatively small they are not by any means as stunted as might be expected. Moreover, little storm-wind damage is to be seen, although there is evidence that 'blow outs' have occurred, having given rise to small areas of nearly even-aged stands.

The next most important species is the hemlock, and this tree also grows to a great size and age in the Queen Charlotte Islands. Without reaching the gigantic proportions of Sitka spruce, it maintains itself well in the canopy, and trees 200–230 feet in height are not rare. This species adds greatly to the beauty as well as to the value of the forests, and in many parts forms a fairly dense undergrowth to the almost entire exclusion of other trees. This is probably due to its

greater tolerance of shade than either Sitka spruce or *Thuya*, and it is difficult to understand why it has not become the dominant species to the almost entire exclusion of the other two. Almost everywhere it grows in mixture with these two species, but the proportions of the mixtures vary according to the locality. On the best sites and soils Sitka spruce and hemlock predominate to a very considerable extent, but as the soil conditions deteriorate *Thuya* takes an ever-increasing part in the crop until on poorly drained swampy land it becomes practically pure.

Hemlock appears to be a more exacting species than Sitka spruce, and whereas the latter species probably reaches its maximum development on the Queen Charlotte Islands, the former finds its 'optimum' somewhat farther south. Again, on exposed parts of the coast Sitka spruce is almost always the tree which takes the brunt of the wind, the hemlock coming in where shelter has been established. Also it would appear that this tree is less tolerant of clay subsoils than either Sitka spruce or *Thuya*. It is a species, however, of good silvicultural characteristics, and the timber is becoming increasingly recognized as of considerable value. For these reasons, and as there are many suitable sites in the British Isles for its growth, it will probably be planted less sparingly in this country in the future.

As has been previously mentioned, *Thuya plicata* is an important constituent of the Queen Charlotte Island forests. It is, however, also a little north of its 'optimum' and while growing to a great age and large dimensions it attains a larger size on Vancouver Island and elsewhere. It is a tree which is very tolerant of water in the soil, and reaches out further into the muskegs than any other species. Its growth is greatly reduced under such conditions, but it forms a crop containing valuable produce such as telegraph poles and poles for piling work, for which its exceedingly durable timber renders it admirably adapted.

The Lodge Pole pine is a comparatively rare species in the Queen Charlotte Islands, but it is found fairly abundantly in parts of the northern half of Graham Island. Here it is found growing with *Thuya* and sometimes Sitka spruce and hemlock on muskeg country with poor drainage. As a timber tree it is of little importance, only reaching a height of perhaps 80 feet in a hundred years and never attaining the size common on the mainland, where its dense growth is the common aftermath of fire.

THE PLACE OF DOUGLAS FIR IN SCOTTISH FORESTRY

BY FRANK SCOTT

INTRODUCTION.

THE tree planters of this country have ever been ready to welcome new species, particularly conifers which have a reputation for timber production. The planting stock of recently introduced species is scarce and therefore expensive, hence special care and favoured sites are given and many have passed their first trials successfully under such conditions. A few have gained the reputation of being 'the thing to plant' on an altogether too slender basis of experience. In a country with varying conditions, such as Scotland, reckless planting of an insufficiently tried species is certain to lead to disappointment, especially when the associated diseases and pests, lagging behind for a period, arrive to find their host uncomfortably situated in its new home. The result may be such as to place it in the category of an undesirable alien, although perhaps unfairly.

Douglas fir appears to be nearing this stage in Scotland at least, and foresters seem inclined to give it the cold shoulder. The time seems opportune, therefore, to consider whether it possesses any good points which entitle it to a place in Scottish silviculture. Unfavourable comment on Douglas fir has recently been heard among various sections of the forestry public. The timber merchant has found difficulty in marketing it, the landowner has been made nervous by the stunt press reporting that a destructive pest is sweeping up from the south and that it will soon destroy every Douglas fir in the country, the forester has found it a difficult tree to establish and when established to keep standing, while the nurseryman finding the market uncertain and rightly following the fashion has reduced his stocks. As a result of this swing of the pendulum the area planted with Douglas fir is annually being reduced.

The object of this paper is to make some observations on the past marketing of and the present prejudice against Douglas-fir timber, and to make some suggestions for the better treatment of plantations of this species.

THE MARKETING OF DOUGLAS-FIR TIMBER.

In considering the future marketing of Douglas-fir timber it is important to review not only the present attitude of the trade towards the home-grown product but the experience of its use and marketing in other countries. It is, perhaps, unfortunate that its timber in a converted state closely resembles that of larch, but cannot be considered to be a substitute for it. About twenty years ago when Douglas-fir timber was first marketed in quantity in this country, it was unknown to the trade, and it could not, therefore, be sold as

Douglas fir. The only alternative to disposing of it in the low-grade classes was to include it in consignments of larch, and in this way considerable quantities were sold. The differences, however, particularly in weight, were soon detected, and it could no longer be sold as larch.

It is also unfortunate that most of the timber converted and sold to date has not been grown under suitable silvicultural conditions, but as isolated trees or in admixture with species which it soon suppressed because of its quicker growth and the shade it gives. In consequence, the timber has been knotty, with wide annual rings, and much inferior to what could be produced in closer and more regular stands.

Two fairly large lots of Douglas fir have been put on the market since the War. One was grown at Gairloch in western Ross and the other at Taymount in Perthshire. The plantations from which these lots were taken were grown under conditions above average but not ideal. The timber was sold, to a large extent, as Douglas fir, though not without some delay and difficulty due to some extent to the poor conditions of the home trade.

The Gairloch timber was converted into a variety of sizes including building timbers. The best of the Taymount lot was cut into railway sleepers, and these were accepted by a railway company at 1*s.* 0*d.* per sleeper less than for Scots pine. In all 10,000 sleepers were converted from approximately 9 acres of plantation. The purchasers were satisfied with the quality of the sleepers, and because of a better intake of creosote they were preferred to the imported 'Oregon pine'.

In the western States of North America, the habitat of the Douglas fir, the lumbermen in early days passed over this species; but since the Yellow pine and other softer and more easily dressed timbers have become scarce, Douglas fir has attained to a very high place in the lumber market. In addition it is of interest to note that in Switzerland, under conditions more nearly akin to our own, Douglas-fir timber has found a definite place. It is used in building construction, including flooring and finishing, and its market value stands between that of larch and spruce.

The chief complaints made against Douglas-fir timber, are its liability to split in nailing, the difficulty in dressing because of the hardness of the knots, and the difference in texture between the spring and autumn wood. On the other hand, the timber has given satisfactory results under mechanical tests, and it is light and durable. In a green state it mills satisfactorily, but is more difficult to saw in a seasoned condition. Though more suitable for heavy structural work it appears to meet the requirements of timbers used in an undressed condition.

No new timber will readily find a place in specifications until it is available in quantity, and has been put to prolonged tests, but there appears no reason to think that the unfavourable impression made by the early open-grown lots will continue. There is no doubt that by better treatment a much superior quality of timber can be produced. In view of its high volume-production, the growing of Douglas fir appears to be justified even if a smaller price than

that of Scots pine has to be accepted, and although its main use is restricted to sleeper production.

SITE SELECTION.

If the mistakes of the past are to be avoided and a better quality of timber is to be produced more care must be taken in site selection. There are certain silvicultural characteristics which must be allowed to govern this selection. Douglas fir will bear a considerable amount of shade, and light shade during the early years appears to be a distinct advantage. The admission of full light, however, is necessary later, if vigorous growth is to be secured.

Next in importance in the selection of site is the question of stability. Except on the most suitable soils, its root development under close canopy is poor and out of balance with its crown development. This is a point to which insufficient attention has been given in the past. Quite remarkable height growth can be obtained on sites quite unfavourable to securing and maintaining a stable crop. On such poor soils as 6 inches of non-fibrous peat over hard stony drift, it has been known to attain a height of 10 feet in 5 years, only to be blown over at this stage owing to the poor root-hold. The soil must be capable of giving stability as well as sustaining growth. Rich soil is not required, but it must be naturally well drained, free in texture, and at least a foot deep. Soils having anything in the nature of a pan should be avoided, and peat-surfaced and leached soils should not be planted with this species.

For the planting of scrub areas in our Highland glens Douglas fir is our best tree because it can be established with less treatment to the existing growth than any other species. Under average birch scrub, it is sufficient to girdle the stems in the year of planting, and the shelter and shade of the birch proves an advantage to the newly planted trees. Losses from transplanting are decidedly less than on bare sites. The girdled birch has died off by the third year and the fuller light necessary for vigorous growth is secured. In the case of hazel scrub strip clearances take the place of girdling. The cleared strips should be about 6 feet wide, and a similar width of scrub left, the planting being in rows 12 feet apart with a spacing in the rows of approximately 3 feet. Oak scrub is more difficult to treat as a rule, but much depends upon its age and vigour. If young, it may be dealt with as suggested for birch; if older, group clearance is better. Areas of weaker growth are removed, and in addition it may be necessary to girdle some stems; this is better done two years in advance of planting. If group clearing is adopted the method of planting suggested by Dr. Anderson (*The Scottish Forestry Journal*, vol. xliv, pt. 2, pp. 78–87) may be used, in which case 70 to 100 groups per acre should be aimed at.

Douglas fir is also suitable for strong-growing bracken on suitable soils. It bears the shade of bracken and will require less weeding than almost any other tree, while because of its rapid growth the weeding period is shorter.

Under all types of vegetation and soil conditions, the stability of the crop is much affected by the amount of water in the soil during windy periods. All sites upon which the flow of water is held up are dangerous. Evenly sloping

ground, or convex slopes, are accordingly best, and concave or cupped configurations should be planted with more wind-firm species.

Douglas fir being sensitive to late and early frosts is not suitable for situations liable to be so affected. It is damaged by smoke and fumes to a greater extent than any conifer at present in general use for planting, and is consequently quite unsuitable for industrial areas.

The site requirements of Douglas fir may be summarized as follows:

(1) A deep, free, and naturally well-drained soil; soils easily saturated, with pan or leached horizons are unsuitable.

(2) Moderately well-sheltered conditions.

(3) Overhead shade such as is given by scrub and strong bracken.

(4) Sites liable to frost or smoke damage are to be avoided.

Douglas fir requires almost as good soil and site conditions as European larch, to which species it must as a rule take second place on bare ground, the latter being the more valuable tree. It will, however, flourish in somewhat poorer soils and should be substituted for larch in scrub and heavy bracken land.

THE REARING OF DOUGLAS FIR.

In general the cost of forming plantations of Douglas fir has been high. This has been due to heavy losses both in the nursery and the plantation, caused mainly by frost damage and particularly by frosty east winds in spring.

A well-sheltered and sloping nursery is required for the rearing of Douglas fir. It should be slightly above the elevation of any valley bottom or flat in the neighbourhood, with an aspect preferably between S. and NW. A well-wooded surround checks the effect of blast, and screens the seed-beds and lines from the sun. The sowing of the seed presents no special problems, but if losses are to be avoided during the seedling stage, both overhead and side protection must be given from September to May of the first year, and from September of the second year until the time of lining-out in the second spring. A good form of protection is supplied by fixing a 9-inch board along both sides of the beds with frames of plaster laths on the top, spaced about half an inch apart. Care in handling between lifting from seed-beds and lining out is of the utmost importance. Both operations should be carried out if possible in dull and mild weather and after east-wind conditions have ceased. Transplanting frames should be used in lining out and the lining trench should be of sufficient depth to allow the roots to hang straight. Hand-laid seedlings are liable to be bent at the root, and these are more likely to suffer wind blow after planting. As a rule, grade I seedlings are large enough for general planting after one year in the lines, but grade II should be relined after one year. The four-year-old, twice-transplanted tree has proved very suitable for bracken and other strong surface-growth conditions. The use of this category of plant greatly reduces losses both from frost and drought and in the end it gives a more stable tree. Trees left for two years in the line, even when wrenched, are apt to become top-heavy through the lower branches being suppressed and the stem becoming spindly. A spacing of not less than 2 inches should be given when relining.

The heavy losses in planting out are largely overcome by a twice-transplanted Douglas fir, and the extra cost of the plant is thus more than repaid.

During the past ten years the number of seasons which have been favourable to the planting-out of Douglas fir in Scotland have been few, namely 1924, 1926, and 1927. During the spring of 1929, a particularly bad season, a trial of twice- and once-transplanted trees was made. Of the former only 4 per cent failed, while the average loss of the latter exceeded 20 per cent. *Phomopsis* damage following frost is very much more prevalent in transplants left undisturbed for two years in the nursery lines.

SPACING DISTANCE.

Spacing distance—a highly controversial subject—must be referred to. The tendency in Douglas fir for strong branch-development and for branching upwards at an acute angle to the stem, is less pronounced when it is planted under scrub. While it is yet too early to form an opinion on the results of the wider spacings adopted in recent years, the indications are that the 6-feet spacing in treated scrub will give a satisfactorily clean crop. On the other hand, trees at this spacing in open ground are developing a very strong and upward-tending branch growth which is persisting for a lengthy period and, even if pruned, will give fairly large knots. Where snow break is not a serious danger, a somewhat less spacing than 6 feet will give a better quality of timber.

Experience indicates that widely spaced trees are more wind-firm and suffer less from snow break than close-spaced. The Taymount Douglas-fir plantation and others, which were originally admixed with larch, but which became very widely spaced at an early stage through the removal of the latter, suffered little from either danger compared with pure and closely spaced plantations of a later date.

METHOD OF PLANTING.

The importance of stability appears to justify a few observations on the effect of method of planting. The root system of the Douglas fir retains for a long period the shape and direction given to it in the act of planting, and does not feather out by adventitious root development like the spruces and other species. The method of planting has, therefore, an important influence on the fixing of the plant, and particularly if the transplants are of large size. No method is fool-proof, but pit-planting appears to be the safest and the only satisfactory method for trees over three years of age. Much swaying has taken place within the past two winters in young plantations which were planted with mattocks. Many such trees have been examined and it has been found that in every instance the roots had been placed in the lop-sided manner difficult to avoid in planting by this method. A satisfactory arrangement of the roots is possible in pit-planting, and doubling up of roots can be avoided. Swayed plants seldom become firm even if set up with turfs or stakes unless the crown is reduced by shortening the side branches and cutting back the leading shoot at a bud or small shoot, which will readily form a new leader.

THINNING.

Perhaps the most critical period in the life of a Douglas-fir plantation is when the pole stage is reached. Failure to take the greatest possible care may lead to disaster.

Thinning is generally necessary by about the fifteenth year, but the age depends upon the original spacing and the rate of growth. It should thereafter be repeated at intervals of three to four years. At the first thinning, groups which are becoming overdrawn and spindly should be relieved, and 'wolf' trees dealt with. The removal of the latter has frequently been the cause of serious wind-break and they usually leave very large gaps in the crop. Except under very safe conditions trees of this class should not be cut out but should be topped sufficiently low to allow their neighbours to get above them. They will then continue to give support to the crop and protection to the soil.

In the early stages the degree of thinning should be regulated so as to maintain such a proportion of crown as will produce a sufficiently strong stem. Stem pruning is necessary for the production of clean timber because the branches of Douglas fir persist for a long time. This need only be applied to such a number of stems as will provide of a selection for the final crop, say 300 per acre. The marking and pruning of selected stems can be carried out conveniently at the time of the second thinning, when the canopy has risen to a sufficient height to give a good view of the stand.

The degree of thinning in the later stages should be regulated to control the diameter increment, as far as this is possible, but in some districts it seems doubtful whether this can be kept below the one inch per three years indicated as desirable by mechanical tests.

PESTS.

The spread of *Chermes* (*Adelges*) *Cooleyi* which had a disturbing influence among foresters has ceased to cause alarm. Two plantations in Perthshire visited in 1928 were found to be covered with these insects, and the height-growth had fallen off from 24 inches to about 6 inches per annum. Revisited in 1930, the plantations were found to be practically free from this pest, and the trees were healthy and recovering rapidly in growth. This has been the general experience in those parts of the country which were first attacked, and nothing more than a temporary loss of increment need be feared.

Among fungous pests, those which attack the tree through its root system are most to be dreaded. *Armillaria mellea* and *Fomes annosus* attack Douglas fir in common with all conifers, but it stands high in the scale of resistance, and this strengthens the case for its use in broad-leaved scrub areas, where these fungi are always present. With regard to the question of root rot, I am indebted to Dr. Malcolm Wilson for the information that the stumps in the Taymount Douglas-fir plantation showed that only 2 per cent of the trees were affected and that the fungus which was responsible was *Polyporus schweinitzii*. The plantation was formed on ploughed land, and it is surprising, therefore, that it remained so sound.

In the light of all available evidence, it is considered that Douglas fir has a definite place in Scottish silviculture. There is no better species for the extensive scrub areas of the Scottish Highlands, but suitable stock must be used, special care must be taken in planting, and the plantations require constant and skilful attention when the pole stage is reached.

STUDIES IN THE BIOLOGY OF *XYLONOMUS BRACHYLABRIS* KR., AND *X. IRRIGATOR* F., PARASITES OF THE LARCH LONGHORN BEETLE, *TETROPIUM GABRIELI* WEISE

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WITH PLATES I AND II

INTRODUCTION.

THE larch longhorn beetle (*Tetropium gabrieli* Weise) which was first described by Weise in 1905 from Switzerland, Austria, and the Tyrol, was taken in Britain in 1901 and 1903. The first detailed study of its biology was made by Crawshay (3) in 1907, who established the fact that the form which occurred in Britain was a variety of Weise's species (*Crawshayi* Sharp) which was apparently confined to the larch. Since that time the only account of the beetle which has appeared in the British literature is contained in the Forestry Commission leaflet (No. 13), written by Dr. J. W. Munro (6) in 1923. In that leaflet Dr. Munro states that the 'Larch longicorn beetle has considerably extended its range in this country since it was recorded in 1903', and that 'the larch longicorn beetle occurs almost all over England but is most abundant in the south. It has not so far been recorded from Scotland.' Discussing the forest relations of the species, Dr. Munro is of the opinion that the chief loss is due to a reduction in the market value of the timber as a result of the borings of the full-grown larvae, but that in big timber much of the tunnelled sapwood is cut away in squaring and dressing, and the loss cannot therefore be considered to be very serious. He even goes so far as to say that the presence of *Tetropium*-infested trees may be a help to the forester, in that they indicate that destructive agents more important than the beetle are at work, and that an examination of the prevailing silvicultural conditions is required. From experience gained through working in larch plantations during the past few years, we are in full agreement with these conclusions. *T. gabrieli* is now extremely abundant in larch woods in the south of England and its association with the blue woodwasp *S. cyaneus* Fabr. in weakly and dying trees has been discussed in a previous paper on the biology of the *Sirex* woodwasps (1). No further studies on the biology of the species have been made in Britain since Crawshay's paper of 1907, but an important paper on this species and an allied one, *T. fuscum*, a borer in spruce, has recently been published by Schimitschek (8), who studied their biology and host-relationships in south Moravia and Lower Austria from 1926 to 1929.

Schimitschek records that the warm dry years since 1921 have caused an

increase in the numbers of both these species, especially in those parts of Austria where the larch and spruce are growing outside, or on the border of, their natural zones of distribution. He finds that *T. gabrieli* is chiefly confined to the larch. The economic loss which these beetles cause as a result of the depreciation in value of the timber may, he thinks, be considerable, and this may be lessened by the good work done by parasites in reducing the numbers of the beetles. He describes experiments which he made with a view to intensifying the parasitism, and which seem to have met with some success.

As far as Britain is concerned, little or nothing seems to be known concerning the parasites of *T. gabrieli*. Crawshay definitely states that no parasites came under his notice, and beyond one statement by E. A. Elliot and Claude Morley (4) which records the breeding of a ♂ *Lissonota* (? *L. palpalis* Thom.) by Mr. Pool at Enfield in 1906 no other records appear to be extant.

The studies described in this paper were occasioned by the fact that the larch longhorn with one of its parasites was found in numbers on a larch area near Brandon, Suffolk, where some investigations on the woodwasp, *S. cyaneus* Fabr., were being carried out. As the work progressed, other areas, for example Tubney Wood, near Oxford, were studied and sufficient material has now been brought together to warrant a short account of the parasites which have come under our notice.

Schimitschek devotes a very large section of his paper to the parasites of the two species *T. gabrieli* and *T. fuscum*. From *T. gabrieli* he bred the Braconids *Atanycolus denigrator* L., *A. nusi* Marsh, *A. sculpturatus* Thoms., *Doryctes obliteratus* Nees, and *Helcon aequator* Nees; the Pimpline Ichneumonids, *Xorides collaris* Grav., *Clistopyga sauberi* Brauns, *Xylonomus brachylabris* Kr., *X. irrigator* F., *Rhyssa persuasoria* L., and the Ophionine, *Pyracmon lucidus* Clement.

Of these parasites, only three have come under our notice: *Xylonomus brachylabris* Kr., *X. irrigator* F., both of which were studied in relation to *Tetropium gabrieli*, and *Rhyssa persuasoria* L., which, although it has been found abundantly in larch woods attacked by *Sirex cyaneus* and *Tetropium*, has always, in our experience, been associated with the woodwasp and never with the longhorn.

THE GENUS *XYLONOMUS*.

The genus *Xylonomus* Grav. which belongs to the sub-family Pimplinae, tribe Xoridides, is represented in Britain by six species. Morley (5) deals with five of these in detail, but makes no mention of *brachylabris*, and when this species was found at Brandon it was believed to be a new record for Britain, a note to that effect being published in the *Entomologists' Monthly Magazine* for December 1928. Subsequently, however, information was received from Mr. A. W. Stelfox of the National Museum of Ireland that the species had been recorded about five years ago by Mr. L. A. Carr, who included it in a list of Ichneumonidae from the Lichfield district, which was published in the Proceedings of the North Staffordshire Naturalists' Field Club.

There are no British host-records for the genus so far as we have been able to discover, and apart from the work of Schimitschek already referred to, the only continental records extant appear to be Ratzeburg's record of *X. precatorius* Fab. as a parasite of *Callidium sanguineum* and *T. luridum*, Briscke's record of the same species as a parasite of *C. variabile*, Ratzeburg's record of *X. irrigator* Fab. as a parasite of *Rhagium indagator*, and the following list of hosts of several species of *Xylonomus* given by Picard (7) in a recent publication on the longicorns of France:

X. irrigator Fab.	*Rhagium inquisitor.*
X. propinquus Toch.	*Hesperophanes griseus.*
X. precatorius F.	*Aromia moschata.*
	Callidium sanguineum.
	Callidium testaceum.
	Tetropium castaneum.

NOTES ON THE FLIGHT PERIOD AND PAIRING HABITS.

The parasite was first observed while carrying out some investigations on the *Sirex* woodwasps in a larch plantation near Brandon, Suffolk, in late September 1928. The larvae of the larch longhorn beetle were present in quantity in these trees and on examining their tunnels in the inner bark, numerous Hymenopterous larvae, enclosed in silken cocoons, were found scattered about the tunnels. It appeared likely that these larvae were parasitic on the longhorn, and a close watch was kept for signs of the adults on or in the vicinity of the trees. Patience was soon rewarded when a ♂ Ichneumonid, which afterwards proved to be *X. brachylabris* Kr., was seen walking about on the bark of one of the trees. The insect appeared to be searching for something, as it kept on tapping the bark vigorously with the tips of the antennae, and after some roving about, finally concentrated all its attention on one particular spot. At this stage of the proceedings the insect was captured and the place which it had been examining so thoroughly, investigated. There, underneath the bark, was found a female, obviously of the same species, which had emerged from the cocoon and was cutting its way out through the bark.

Observations made at Tubney Wood, Berks., in September 1929, revealed the presence of the species in that locality, and on three occasions the males were observed wandering over the bark and searching the surface with their antennae in the manner above described. It is highly probable that these males were awaiting the emergence of the females, specimens of which were afterwards bred out in the laboratory, although only one specimen was actually seen in the wood itself.

Flight period. The flight period usually commences about the latter half of May, although one very early record of emergence was made on 3 May 1929, when two males emerged in the laboratory. The maximum emergence occurs during the month of August, but adults continue to emerge until about the middle of October. As with many other parasitic Hymenoptera, the males usually appear first, and the observation, already recorded, of their roving about

the bark awaiting the emergence of the females is interesting, in view of similar observations which have been made by Gade, Champlain, and Barlow in the case of North American species of *Megarhyssa*, a parasite of the *Tremex* woodwasp, and by Chrystal (2) in the case of *Ibalia leucospoides* Hochenw., the Cynipoid parasite of the *Sirex* woodwasp, *S. cyaneus* Fabr.

As is the case with other parasitic Hymenoptera, the adults are sun-loving insects, retiring in dull and rainy weather under the shelter of the bark scales.

Pairing. The act of pairing has never been observed in the open, but has been repeatedly observed in the laboratory. The male approaches the female with his antennae vibrating rapidly and on reaching her, gently brushes her antennae with his own. This preliminary to the pairing act has also been described by Chrystal (2) in *Ibalia leucospoides* Hochenw. as being a constant feature. Very gradually the male approaches the female until he comes into close contact with her, the antennae continuing the stroking action all the while. While pairing is in progress, the female stands in a somewhat crouching attitude, with the wings slightly raised and the antennae directed forwards in some cases, whilst in others she may busy herself with the task of cleaning them with her front legs. The male, meanwhile, clings tightly to her with all six legs, his abdomen curled round hers and the tip inserted into the body at the base of the ovipositor.

He continues to stroke the thorax of the female with his antennae during pairing, and the abdomen keeps up a pulsating movement at regular intervals throughout the operation. Pairing may last from 15 to 40 minutes, the usual period being about 20 minutes, and during pairing the ovipositor of the female always points straight backwards. The variation in size of both sexes in this species is, as in many other Hymenoptera, considerable, and in cases where very small males have been observed to pair with very large females, the male takes up a position either lying across the abdomen of the female, or clinging to her ovipositor with the first two pairs of legs, using his wings to balance himself.

Oviposition. While oviposition has only been observed once in the open, numerous opportunities have offered for its observation in detail in the laboratory. The female walks along the log with her abdomen moving slightly up and down, and her antennae either exploring the bark with a wide sweeping motion or tapping the surface and exploring every crevice. This may continue for some time until she suddenly stands quite still with her antennae either resting upon the bark or directed straight forward. She then proceeds to examine the place with particular interest, walking all round it tapping and exploring the bark surface. Once satisfied that her quarry lies below she raises her wings very slightly and standing on the tips of her hind legs she raises the abdomen vertically upwards and turning the ovipositor towards the surface of the bark, commences to bore (Plate I, Fig. 1). During this operation the insect shows great skill in retaining her balance under circumstances which are often difficult, and only rarely does she lose her balance and fall off the log.

When oviposition begins the ovipositor is still encased in its sheaths, the whole organ being driven with a semi-twisting motion of the abdomen, suffi-

ciently far into the bark to enable her to balance herself with greater ease, this part of the operation usually taking from 10 to 15 minutes, after which time the sheaths are slowly withdrawn and resume their normal horizontal position. Meanwhile the insect continues to drive the slender ovipositor more deeply into the bark, the abdomen assisting in the operation by short vertical movements, but the actual boring work being done by the toothed stylets of the ovipositor. As the ovipositor descends deeper into the bark the abdomen becomes slightly curved and the sheaths are directed upwards. The wings are as a rule folded over the back in their normal resting position. The ovipositor usually enters the log at an angle which may be as high as 50 to 60°, and the pressure exerted upon it when boring is taking place is at times so great that it becomes distinctly arched.

When the required depth has been reached the insect stands quite motionless for perhaps 5 to 15 minutes. The accuracy with which she locates the host larva is very great, as in the majority of cases examined the egg was laid on its body. Only very exceptionally was the egg found lying on the floor of the tunnel beside the host. No cases have been observed of the insect boring in places where the host larva was not present, as is so often the case with *Rhyssa*.

The ovipositor is withdrawn from the bark by short upward jerks of the abdomen. When free, the insect standing on the two front pairs of legs brushes off with the hind legs any particles of sawdust which may have adhered to it and replaces it within the protecting sheaths. The time required to complete oviposition varies from 15 to 40 minutes, but 30 minutes is the usual period. Some females were observed remaining for many hours with the ovipositor in the same place. Thus a large female was observed to commence ovipositing in the laboratory at 11 a.m. on 14 October 1929, and after having been kept under constant observation was found with her ovipositor inserted in the same place at 3 o'clock that afternoon. On examination of the place a *Tetropium* larva was found which had apparently been paralysed, but there was no sign of an egg on or near its body. Females have also been observed in the laboratory ovipositing until late at night and in the early hours of the morning.

Oviposition completed, it is usual for the insect to stand over the place for a few minutes before moving away to repeat the operation elsewhere.

The ovipositor, which in the female may vary from 7 to 11 mm. long, is often inserted into the bark for more than three-quarters of its length, in the remarkably short time of 15 minutes. The insect always chooses a bark crevice should one be available, but she will just as readily pierce the solid bark. She will sometimes return to a place where she has already oviposited and commence oviposition for a second time. This has been observed on two occasions and on one of these it was found that two eggs had been laid on the same host larva, but in the other case only one was found. In our experience it is very rare to find two eggs laid on one host.

Notes on Host Selection. In order to ascertain whether the parasites would attack the larvae of longhorns other than *Tetropium*, several males and females of *X. brachylabris* Kr. and *X. irrigator* F. were placed in a cage along with a

number of larch logs under the bark of which the larvae of *Tetropium* and a number of other longhorns had been placed. It was not long before the parasites began searching the logs in quest of their prey. *X. brachylabris* Kr. was observed to oviposit three times, in each case over the place where a *Tetropium* larva was lying. On only one occasion did the parasite investigate the location of a larva other than *Tetropium*, but her examination was brief and it was fairly obvious that these other larvae did not attract her.

At a later stage of the experiment spruce logs were introduced into the cage. In these the larvae of *Molorchus minor*, a spruce longhorn, were boring. *X. brachylabris* never took any interest in these logs, but *X. irrigator* was seen attempting oviposition on several occasions without, however, being successful in any particular case.

THE EGG, LARVAL, AND PUPAL STAGES.

The Egg. The egg of the parasite is generally found attached to the dorsal surface of the body of the host larva. It may be laid on any part of the body, having been found on the tail, in the middle, and near the head. Only once has the egg been found lying in the bottom of the tunnel 3 mm. from the head of the host (Plate I, Fig. 2). The egg is markedly fusiform, with a short transparent pedicel at one end, the central two-thirds milky white in colour with a yellowish tinge plainly discernible in the middle, while the head and tail are of a glassy transparency. The surface of the chorion examined under a low power is quite smooth except for very faint longitudinal lines. The egg measures 1·7 mm. in length and 0·27 mm. in diameter in the middle. The pedicel measures 0·4 or 0·5 mm. in length, so that the total length of the egg and the pedicel is about 2 mm.

Hatching-Period. The appearance of the egg alters very little until the third day after oviposition, when it turns a creamy colour with the yolk more definite. After six or seven days the embryo can be distinctly seen moving within, its head pointing toward the rounded end of the egg. On the eighth or ninth day after oviposition the young larva bites its way through the egg-shell, an operation which it completes in about one hour, leaving the empty egg-shell, which soon shrivels up, still fixed to the body of the host. The average hatching-period is approximately eight days, and in no case has it been found to exceed nine.

The First-Stage Larva. The first-stage larva prepares to attack the host immediately on completing its emergence. It spends the first hour or two moving about on the body of the host, which it does with great rapidity despite its legless condition. At the end of this time it is firmly attached to the host with its mandibles buried in the tissues. The preliminary feeding is more in the nature of suction of the fluid body-contents than tearing of the solid tissues with the mandibles. In the case where the egg of the parasite was found lying at a distance of 3 mm. from the host, the young larva on hatching found no difficulty in crawling to the body of the host and attaching itself at the tail end.

The growth of the young larva is very rapid. On emergence it measures

1·3 to 1·5 mm. in length, and at the end of twenty-four hours the length increases to 1·8 mm. Up to this time, although apparently paralysed and injured by the feeding of the young larva, the host is still alive, as a study of its heart-beat, which is faint though discernible, has shown. Six to seven days after hatching the young larva moults for the first time. The integument splits longitudinally and is gradually rolled backwards until it falls away from the body a few hours later. Immediately before moulting the larva measures 3 to 3·5 mm. so that the average increase in length per day during the first stage is approximately 0·5 mm.

Moulting does not apparently affect the larva so far as feeding is concerned as it has been observed to continue doing so throughout the operation.

The Second-Stage Larva. The second-stage larva (Plate I, Fig. 3) does not differ greatly in shape from that of the first stage, and it continues to feed and increase in length at about the same rate. By the time the second skin is cast on the fourth or fifth day after the first moult, the larva has attained a length of 5·3 to 5·4 mm. The host larva is dead by this time, and the shrunken appearance of the central portion of the body bears testimony to the increased intensity of feeding of the parasite.

The Third-Stage Larva. In this, the penultimate stage, the larva assumes a general shape characteristic of the Pimpline larval type. Twenty-four hours after moulting its length is approximately 6 mm. The third stage lasts from six to seven days, and by the time the larva is ready to moult for the third time it has attained a length of from 7 to 8 mm. By this time almost two-thirds of the body-contents of the host have been consumed and, despite the fact that a period of fifteen to eighteen days has elapsed since the attack on the host began, the remaining portion of the body-contents appears to be quite fresh. An interesting observation was forthcoming in one case where a female had oviposited twice on the same host. On 25 September 1929, a female oviposited in the same place twice, and on 5 October 1929, two healthy third-stage larvae were found feeding on the same host (Plate I, Fig. 4). At the end of six days the host larva had been consumed and one of the parasites had attained a length of 8 mm. and had begun to eat the other, which apparently had been starved and only measured 5·3 mm. Ten days later only the skin of the smaller parasite larva remained and the other, now measuring 11 mm., was lying resting in the tunnel prior to spinning its cocoon.

The Fourth-Stage Larva. The larva just after moulting measures 8 to 9 mm. in length. It continues to feed on the remaining portion of the host, which is completely consumed after five or six days, only the chitinous exoskeleton and head-capsule remaining, which soon dry up and are pushed by the parasite larva to one end of the tunnel. The larva now varies in length from 7 to 12 mm., depending on the size of its host. Feeding completed, a period of two to five days elapses, during which the larva lies motionless in the cell. At the end of this period it begins to show signs of activity and commences to construct the cocoon. This is effected in the first instance by moving the head backwards and forwards towards the tail end of the body, thin longitudinal threads of silk issuing from the mouth region as the operation proceeds (Plate I, Fig. 5).

The larva begins spinning its cocoon by drawing a series of silken threads from head to tail along the ventral side of the body and about half-way up the pleural region. Following this proceeding it begins to twist its body about in such a way as to draw the silken threads in a circular manner around the body. The cocoon is half-finished on the second day and completed in from three to five days. When completed the walls of the cocoon appear thin, shining, and transparent, and the cocoon is anchored to the sides of the cell by means of silken threads. The cocoon completed, the larva frees the tail end of its body from the silken threads which attach it to the cocoon and now lies free within. The cocoon is rounded at both ends and usually measures about twice the length (13 to 20 mm.) and twice the diameter (3 to 5 mm.) of the larva. By the end of the third week of October the majority of the larvae have finished spinning their cocoons and can now be found lying motionless within them, a condition which lasts throughout the whole of the winter and into the early summer of the following year.

The Prepupal and Pupal Stages. The fourth-stage larvae are found in the prepupal stage from the end of April until the beginning of September. At the beginning of this stage the skin of the larva becomes limp and in two or three days the pupal eyes are faintly visible beneath the skin. These darken in colour fairly rapidly and on the seventh or eighth day the larval skin is cast, revealing the fragile pupa which, with the exception of the eyes, is shining white. On the second or third day after the casting of the larval skin the head and thorax of the pupa turn a brownish colour, the antennae, legs, and abdomen remaining unchanged. By the sixth day the head and thorax are shining black in colour; the dorsal surface of the abdomen has begun to darken; the basal joints of the antennae have begun to colour, and the coxae and trochanters of all the legs turn brown. On the ninth or tenth day the pupal exuvium splits down the back, revealing the imago whose antennae are coloured for half their length, the remaining joints being still white and covered by the pupal exuvium. The remains of this are rapidly shed and on the following day only the tips of the antennae, hind legs, and ovipositor are enclosed in it. The wings are now fully extended and lie folded over the back, while the abdomen is black except for a white strip on the ventral and pleural regions. By the twelfth day the imago is well formed, only the terminal joints of the antennae and the tips of the ovipositor sheaths remaining uncoloured. The insect is fully developed and ready to emerge on the fourteenth or fifteenth day.

ON THE OCCURRENCE OF THE INSECT IN LOCALITIES OTHER THAN BRANDON.

The major portion of the material which has been used in the present investigation came from Brandon, Suffolk, but the insect was also taken during the summer of 1929 and subsequently, in Tubney Wood, and Bagley Wood, Berks. In both localities considerable numbers of the larvae were found lying in their cocoons in larch trees which had been heavily attacked by *Tetropium*. No records have been made of the parasite's presence in any other locality, but

it is extremely probable that owing to the wide distribution of *T. gabrieli* throughout the south of England, *Xylonomus brachylabris* Kr. will be found to have the same distribution as its host.

ON THE PARALYSIS OF THE HOST LARVA BY THE PARASITE.

No direct evidence has been obtained on this point as the parasite has never been observed to sting the host. From indirect evidence, however, it is probable that the host is paralysed by the parasite at the time of oviposition. Observations made on the larvae of *Tetropium* have shown that they exhibit great activity when exposed to light and that under normal conditions they are capable of boring for a distance of over half an inch in the space of a few days. Parasitized larvae, on the other hand, do not exhibit the same activity when exposed to light and have not been observed to bore at all subsequent to being parasitized.

It is in fact highly probable that as the hatching-period of the parasite's egg is from 7 to 8 days it would run a grave risk of being destroyed should the host larva remain in a fit condition to bore in a normal manner.

Examination of the host larva under the microscope has shown small punctures on the fourth abdominal segment. It is not certain, however, that these punctures were made by the ovipositor of the parasite.

Records which have been taken of the heart-beats of a number of normal and parasitized larvae have shown that there is a marked difference between them. The average heart-beat of a normal larva, taken over periods of three minutes, varies between 18 and 22 beats per minute, while the heart-beat of parasitized larvae is very faint and irregular and only averages 7 to 11 beats per minute over the same period.

Similar observations made in the case of *Rhyssa persuasoria* L., the parasite of the *Sirex* woodwasps, and *Thalessa curvipes* Grav., the parasite of the *Xiphydria* woodwasps, have shown that the host larvae invariably exhibit the same inertia of movement and of reduced heart-beat. In the case of *Rhyssa* definite evidence was forthcoming of the penetration of the host's body by the ovipositor.

Another interesting observation may be cited in this connexion. In the case of one *Tetropium* larva parasitized by *Xylonomus* in August 1930, the egg of the parasite perished at the end of three days. The host larva, which was kept under careful observation, remained quite fresh but exhibited no symptoms of renewed activity, finally perishing after some six weeks had elapsed.

PERCENTAGE OF PARASITISM.

While the amount of material collected in the three localities—Brandon, Suffolk, Bagley and Tubney Woods, Berks.—has been insufficient to allow of any very definite conclusions being drawn as to the average percentage of parasitism, one or two interesting observations have been made. In the first place it appears that in all localities the numbers of parasites vary widely in different trees. In Tubney, for example, an examination of two larches standing quite

close together, and equally badly infested with *Tetropium*, showed that while one contained a considerable population of *Xylonomus*, the other contained none at all. Actual figures for the percentage of parasitism in the different areas give an average of 59·5 per cent for Brandon, 39·3 per cent for Tubney, and 16 per cent for Bagley.

OBSERVATION ON PARTHENOGENESIS. PROPORTION OF THE SEXES.

One case of parthenogenesis has been observed. The first female of *X. brachylabris* Kr. was taken at Brandon in September 1928, before it had completed its emergence. It was brought to the laboratory and placed in a cage containing *Tetropium*-infested logs. It oviposited in 10 to 12 host larvae and four of the eggs laid were kept under observation. In May 1929, the larvae from these eggs pupated and emerged as males.

As regards the proportion of the sexes, observations made during the summer of 1929 showed that out of a total of 231, 95 were females and the remainder males. Similar observations made during the same summer on *Rhyssa persuasoria* also showed a predominance of the males over the females, while in the case of another Ichneumonid parasite, *Thalessa curvipes*, the proportion of the sexes was about equal. The records for previous years in the case of *Rhyssa* and subsequent records made in the case of *Xylonomus* have not shown this excess of males over females, the proportions being rather reversed. This predominance of males during 1929 must therefore be regarded as unusual.

A HYPER-PARASITE OF *XYLONOMUS*, *CALOSOTA ANGUINALIS* RUSCHKA, *HYMENOPTERA*, *EUPELMIDAE*.

While searching for the pupae of *Xylonomus brachylabris* Kr. during the first week of November 1928, two cocoons containing well-coloured female pupae were found. Two small parasite larvae were within these feeding on the pupae. These measured at this time about 2 mm. long and had well-chitinized heads and a tapering body, each segment of which bore a ring of long hairs which gave the larva a conspicuous appearance. The larvae were left undisturbed until the middle of December, by which time they had grown considerably, having consumed the greater part of the host. They were not examined again until some three months later, when they were found to be full-grown and lying inert within the cocoon. A period of seven months then elapsed before they were examined, when it was found that pupation had taken place and the adults emerged sometime during the summer. The species was identified by Dr. Ferrière of the Imperial Institute of Entomology, who stated that it was of very rare occurrence and only previously known from Germany. Its appearance as a hyper-parasite is also apparently new, as previously it has only been recorded as a parasite of wood-boring beetles.

XYLONOMUS IRRIGATOR F.

This species was first found in Tubney Wood in 1928, flying around and inspecting the stems of *Tetropium*-infested larch. The insect was not found at

Brandon but appears to be more common at Tubney than *X. brachylabris* Kr. According to Dr. Ferrière *X. irrigator* F. is more widely distributed in Britain than *X. brachylabris*.

Subsequent observations showed that the adults did not emerge until the first week of July, and that the height of the flight period was reached at the same time as that of *X. brachylabris*. As in that species the males emerge first and seek out the females by locating the place from which they will emerge.

The pairing and oviposition of the species do not differ in any important respect from that already described. The eggs are generally laid on the dorsal side of the host and differ somewhat in shape from those of *brachylabris*, having little or no pedicel and being generally stouter in form. They measure 1·75 mm. long by 0·5 mm. broad.

The duration of the larval stages agrees also, and the full-grown larva remains inactive in the cell before spinning its cocoon. The cocoon is markedly different from that of *brachylabris*, being dark mahogany-brown in colour, in contrast to the white transparent cocoon of the latter species. This marked difference between the two cocoons makes them easily separable where they are present together. The pupal stage of the parasite does not differ in any marked degree.

NOTES ON THE MORPHOLOGY OF THE HEAD OF THE LAST-STAGE LARVAE OF *X. BRACHYLABRIS* KR. AND *X. IRRIGATOR* F.

Thorpe in his recent paper (9) on the parasites of the Pine Shoot moth, *Rhyacionia* (*Evetria*) *buoliana* Schiff., has discussed the morphology of the larval head in the Ophionines—*Omorgus borealis* Zett.; *O. mutabilis* Holmg.; *O. ensator* Grav.; *Cremastus interruptor* Grav., and *Eulimneria rufifemur* Thoms.; the Braconid, *Orgilus obscurator* Nees; and the Pimplines, *P. examinator* F., *P. brevicornis* Grav., and *P. ruficollis* Grav.

The following elements are distinguished by Thorpe as providing the ground plan of the tentorial structures in the Ichneumonidae:

Mouth parts: Labrum, mandibles, maxillary palpi, labial plate, labial palpi.
Tentorium: Labral strut, mandibular strut, maxillary strut, labial strut, labial ring.

A careful study of preparations of the larval heads of both species of *Xylonomus* has shown that all these elements can be easily distinguished and a brief description of them is given here together with a figure of the larval head of *X. brachylabris*. This has been included in this paper in the hope that it may provide further material for future comparative study of the Ichneumonid larvae, about which our knowledge is at present comparatively limited.

The first organs to be noted are the antennae, which lie outside of and slightly above the labral struts. They are set in smooth non-chitinized areas and have the conical shape usually met with in this type of larva. From the antennae we pass to the labral struts (*Lbr. St.*). These are somewhat sinuous in outline, tapering at their apices, and becoming much broader and more heavily pigmented at their bases where they fuse with the mandibular struts. About halfway down their inner margin there is a prominent process with which the upper

portion of the mandible articulates. Immediately below the labral struts lie the mandibular and the maxillary struts which together form a Y-shaped structure with a long stem and well-developed arms. The lower arm, which is the maxillary strut (*Mx. St.*), is the longer of the two and slopes downwards, passing underneath the labial strut. The upper arm is the mandibular strut (*Md. St.*). With this the lower portion of the mandible articulates. It also appears that the mandibular struts are in these larvae prolonged backwards and fuse with each other posteriorly to form an indistinctly pigmented ring. It is possible that this ring is similar to that described by Thorpe in *O. obscurator* Nees (*loc. cit.*, p. 405). Articulating with the labral and mandibular struts are the mandibles (Plate II, Fig. 1). These are triangular in shape at the base and when viewed *in situ* they are seen to terminate in two large straight-pointed teeth which tend to lie slightly one above the other. The inner portion of the mandible is deeply concave and each side of the concavity is flanked by a ridge which is crowned for the greater part of its length with a row of much smaller but still quite solid teeth. These teeth appear to be much more formidable than the 'stiff, bristle-like hairs' described by Thorpe in *Pimpla ruficollis* Grav.

The labrum is faintly chitinized and the arrangement of the principal spines and sensillae on it is as follows. On either side of the middle line close to the front margin a group of two small spines. Above these is a row of four prominent spines placed somewhat diagonally. Immediately behind these is a scattered group of sensillae containing four elements on the one side and five on the other, while lying externally to these near the outer lateral margin are a number (four to five) of smaller spines. Still further back and lying nearly parallel to the apices of the labral struts there is on either side of the median line a single sensilla flanked outwardly by two large spines.

Below the mouth lies the well-pigmented labial ring (*Lab. R.*) enclosing the labial plate.

The labial ring in *Xylonomus* is broadly rounded at the base, the well-chitinized lower margin bearing numerous small blunt teeth. The sides decrease in width and are somewhat arched, showing a distinct constriction for the apical third of their length. The ends of the ring are pointed and tend to curve in towards one another when viewed on a larva prior to mounting. The drawing, Plate II, fig. 2, does not indicate this sufficiently, as it was made from a head after mounting, the pressure of the cover glass having the effect of drawing the ends out so that they appear more or less parallel. The pointed apices of the labial ring in the *Xylonomus* species are quite distinct from the broadly rounded apices found in certain species of Pimpla (*P. brevicornis* and *P. ruficollis*). Lying at the sides of the labial ring, running parallel to it, and almost touching it for part of their length are the labial struts (*Lab. St.*) which, as mentioned above, lie over the ends of the maxillary struts. These structures are also well pigmented. Lying between the arms of the Y formed by the mandibular and maxillary struts, and immediately below the mandibles, are the maxillary sensillae (*Mx. S.*). These sensillae are enclosed in a definite ring and resemble in form the sensillae figured by Thorpe for the Pimplas. Corresponding to

PLATE I

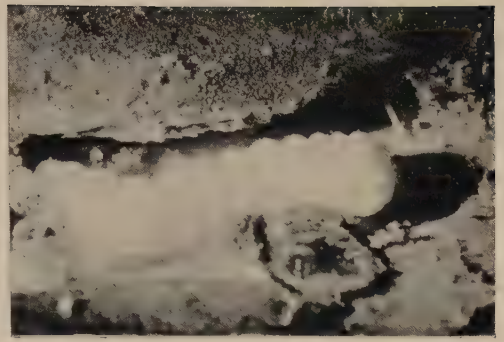

FIG. 2

FIG. 1

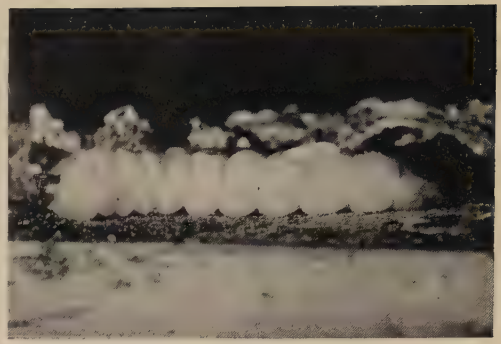

FIG. 3

FIG. 4

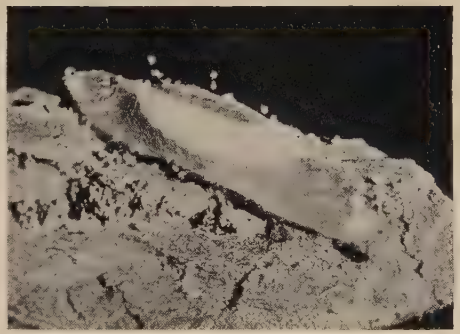

FIG. 5

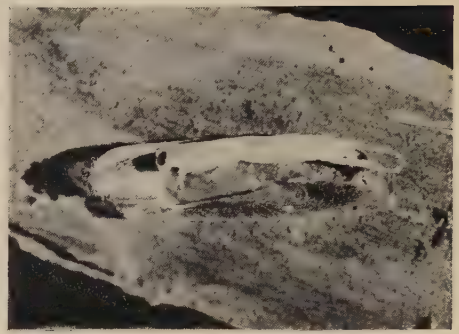

FIG. 6

1

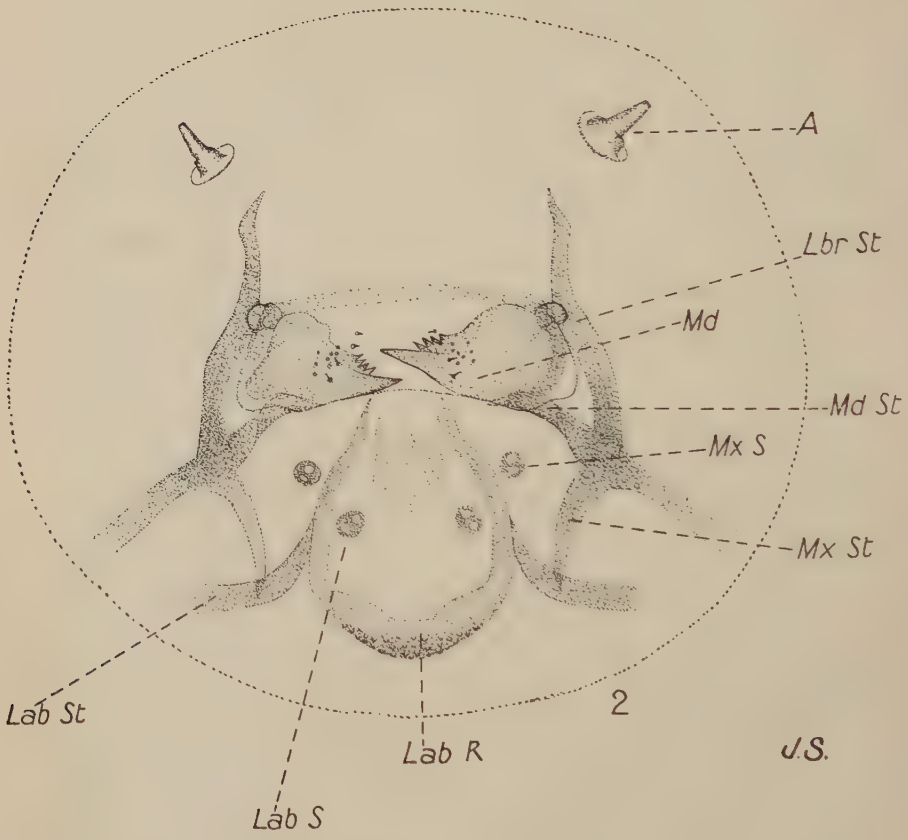

PLATE II

these there are on the labial plate the labial sensillae (*Lab. S.*) which are similar in structure in every detail. These maxillary and labial sensillae are believed to represent the maxillary and labial palpi respectively. Lying below the labial sensillae there are four well-marked spines placed in a transverse line, the two outermost lying near the margin of the ring, the two innermost lying one on either side of the middle line. There is no trace on the labial plate of any distinct pigmented area such as the Y-shaped patch which is such a conspicuous feature according to Dr. Thorpe in certain Ophionine species.

Similar studies to the above were made in the case of *Xylonomus irrigator*, but in comparing the mounts with those of *X. brachylabris* no striking difference between the two species could be found with respect to the mouth parts and tentorial structures.

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EXPLANATION OF PLATES I AND II

PLATE I

FIG. 1. *X. brachylabris* Kr. Female ovipositing on larva of *Tetropium gabrieli*. × 1.5
FIG. 2. Egg of *X. brachylabris* lying in the cell near the head of the *Tetropium* larva. × 2.
FIG. 3. Second-stage larva of *X. brachylabris* feeding on *Tetropium*. × 2.
FIG. 4. Two third-stage larvae of *Xylonomus* feeding on the same *Tetropium* host. × 1.75
FIG. 5. Fourth-stage larva of *Xylonomus* lying in the newly spun cocoon. × 2.
FIG. 6. Early pupa of *Xylonomus* removed from the cocoon. × 2.

PLATE II

FIG. 1. *Xylonomus brachylabris* Kr. Left mandible—side view. × 300.
FIG. 2. *X. brachylabris* Kr. Fourth-stage larva—face view. *A.*, Antennae; *Lbr. St.*, Labral strut; *Md.*, Mandible; *Md. St.*, Mandibular strut; *Mx. St.*, Maxillary strut; *Lab. St.*, Labial strut; *Lab. R.*, Labial Ring; *Mx. S.*, Maxillary Sensilla; *Lab. S.*, Labial Sensilla.

SQUIRRELS AND FORESTRY

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THE depredations of the British red squirrel (*Sciurus leucorus*) are well known to the older foresters, and one has only to examine a forty- to fifty-year-old stand of Scots pine anywhere in the north of Scotland to understand the reason for the rigorous warfare that was waged against these charming little rodents during the early part of the present century—which to nature-lovers in the south of England now seems a crime of unthinkable brutality. Many curious and interesting events have been taking place in the squirrel world during the past fifty years, which make it impossible to write about squirrels in relation to forestry without considering both their past and future history.

At the time of writing the red squirrel is so scarce throughout the British Isles that even in its most favoured strongholds, such as Speyside, one can walk for days through pure pine woods without seeing a single squirrel. About 1895 to 1905 squirrels appear to have been very numerous in practically every favourable locality throughout Great Britain, and were a great trouble to the forester; but from 1905 onwards the squirrel populations in various parts of the country became subject to sudden and violent reductions in numbers, quite apart from the stern measures that were being taken against them by every one interested in forestry. The earliest instances of this decrease in numbers are recorded from the south of England, and in nearly every case on which reliable and careful observations were made the cause appeared to be an epidemic disease of unknown nature. Generally speaking, it appears that in practically every part of England and southern Scotland there was a sudden reduction in numbers at some time between 1904 and 1915, followed by a further gradual decline over the next ten years or so. In northern Scotland there is less evidence of a pronounced drop in numbers at any one time, but the records from various estates show that the numbers were at a peak about 1907–9, and thereafter declined considerably in spite of periodic revivals about 1917 and 1923. By 1930 the red-squirrel population in most parts of northern Scotland was at a lower level than at any time during the previous forty years. Very little evidence of disease has been obtained from northern Scotland, but it was noticed to be prevalent in Forfarshire at various times between 1920 and 1930.

It may be argued that the enormous areas of woodland felled between 1914 and 1918, and the persistent war on squirrels by foresters would be quite enough to account for the present scarcity in Scotland, if not in England. This, however, is not borne out by observations on particular areas, and the fact that the same decrease has occurred on estates where squirrels are not killed. There

is no doubt that the amount of woodland felled during the Great War is in no way proportional to the reduction in the numbers of squirrels, and there are now large areas in various parts of Great Britain that could readily support twenty times their present red-squirrel population.

Beyond the fact that virulent epidemics occur periodically among squirrels, rabbits, mice, and other animals in all parts of the world, extremely little is known about disease amongst wild animals. In the past, information regarding the occurrence of such epidemics has not usually reached the scientific investigator until several years after the event; consequently, even if adequate laboratory facilities had been available for studying animal diseases—which is still far from being the case—the lack of an effective intelligence system, and of co-operation between the observers on the spot and the scientific workers in laboratories, made any satisfactory research into the causes of squirrel epidemics very difficult and impracticable. It is hoped that instances of this nature in the future will be more thoroughly investigated, because any knowledge of animal diseases would be an important contribution to pure science, and might become of practical application as a means of control for animal pests.

Since 1927 it has been noted in many districts of England that the numbers of red squirrels appear to be recovering from this period of intense depression, and during 1929 and 1930 definite increases were reported from various localities. It now seems probable that the squirrel is at the beginning of another period of increase and prosperity, similar to that resulting in the high numbers at the beginning of the present century. If British squirrels are subject to the periodic fluctuations in numbers so common among most rodents throughout the world—and there is every reason to believe this to be so—it is probable that the forester will experience a return of his troubles with these rodents about 1940 to 1950 that he hardly anticipates at the moment.

There is now a new factor influencing both the red squirrel and the forester, and what effect it will have upon the increase of the former we do not yet know: about 1890 a few American grey squirrels (*Sciurus carolinensis*) were brought to this country and liberated in a private park. From this introduction, and from other secondary centres, the grey squirrel has now spread over a large area of the country, including in its range the whole of south-eastern England and the Midlands, extending westwards through Gloucestershire, and northwards into Leicestershire. A large part of Cheshire and part of north Wales are covered, while most of Yorkshire has been populated from two independent centres. There are also grey squirrels in the neighbourhood of Bournemouth, Exeter, Nottingham, and Edinburgh. In Scotland the most important areas covered are the whole of western Dumbartonshire and the Dunfermline district. In Ireland there is one centre in county Longford, from which grey squirrels have spread for several miles around.

The grey squirrel is a native of the north American hardwood forests; in the British Isles, also, it seems to favour deciduous rather than coniferous woodlands. It is a much larger animal than the British red squirrel, adult specimens measuring: head and body length, about 12 inches; tail length, about 9 inches.

The general colour effect is silver-grey, but there is a good deal of russet-brown coloration on all specimens. This brown colour is usually prominent on the top of the head, the centre of the back, and on the upper surface of the feet and ankles; the individual hairs show several colour zones of black, brown, and white, which are especially noticeable in the long hairs of the tail. There are no tufts on the ears. Albino specimens are not uncommon, and in one district of Bedfordshire a pure black variety is now quite common.

Owing to the large area of country covered by the grey squirrel, its distribution from so many centres, and the rapid rate of its increase, there seems little doubt that in future forestry will have to add it to the permanent 'vermin list'. The population in the area covered up to date is by no means uniform, and there seems to be a marked tendency for grey squirrels to congregate in particular localities, rather than disperse evenly in all favourable habitats. In some localities in the south of England a concentration of at least 3 per acre has been attained at certain times. The grey squirrel seems to extend its range very rapidly by the migration of isolated pairs or individuals; pairs often seem to trek twenty miles or more before settling on a breeding-site, and in this way colonies are started at considerable distances from any previously populated area. In America, mass migrations of thousands of grey squirrels sometimes take place, but so far there are no records of this from the British Isles.

Generally speaking, the habits of the grey squirrel are similar to those of the red, but it certainly spends more time on the ground than the British squirrel, and frequently takes cover in a rabbit-burrow when hard pressed, rather than at the top of the nearest tree—as we expect a squirrel to do. As far as our knowledge goes—but there is very little accurate evidence on this point—it appears that the grey squirrel breeds at a slightly higher rate than the red, usually having about 4 to 6 young in a litter, and often two litters in a breeding-season. The nests are usually large spherical structures, roughly constructed of twigs and leaves. The grey squirrel generally uses twigs with the leaves still on them, mostly taken from the tree in which the nest is built, whereas the outer portion of the red squirrel's drey is usually made of dead twigs without the leaves. Many nests made are merely 'sitting-out places', and only used for a short time, but the breeding nests are large and usually solidly built into a main fork of a tree. Wherever possible, hollow trees seem to be used for breeding-nests and winter quarters, while several instances are recorded of them living and breeding in the roofs of old buildings. The young are usually born from March to May, and, as far as is known, do not themselves breed until the following year.

The precise effect that this alien squirrel will have upon the red squirrel population of the British Isles is difficult to determine at the present stage; but there are many records of actual combat between the two species, generally resulting in victory for the larger and more powerful grey. The grey squirrel, however, shows a decided preference for a habitat of mixed deciduous woodland, while the ideal home of the red is undoubtedly the pure coniferous forest; hence it seems probable that a large population of both species may exist in the future,

their distribution being determined to a great extent by the two types of woodland. At the present time there are very few large areas of mature coniferous forest, except in the north of Scotland, but the afforestation now proceeding will provide extensive tracts within the next fifty years, thus forming clearly marked habitats suitable for the red squirrel, and probably less suited to the more omnivorous grey species.[1]

Most foresters know a great deal more about the damage done by squirrels than I can profess, but for the benefit of those who have not had experience of the subject it would be as well to summarize the evidence derived from the observations of foresters and others in various parts of the country. The majority of the damage done by the red squirrel has occurred in coniferous forests, especially in pure Scots pine areas; it may therefore be of interest to discuss briefly the normal food of squirrels in a pure pine forest throughout the year. From April onwards until the end of the summer, a large part of the red squirrel's diet consists of young green shoots and buds. From the middle of May until the end of July, the succulent inner bark of young pines becomes an important food, and any birds' eggs found in the spring appear to be eaten with avidity. Cones are probably used all the year round, even in the unripe condition of summer, but nothing except the seeds appears to be eaten, although the scales of the green cones appear to be quite palatable. From September until April there is little variety of food in a pine forest, except seeds from cones, fungi, and such bulbs and rhizomes as can be found by the squirrels; fungi form a much larger proportion of the autumn and winter food than is generally believed, and it seems to be a common practice for squirrels to hang up various species of fungi in the branches of the trees to dry. In the less specialized habitats, such as mixed woodland and park lands, the food of the red squirrel is much more varied at all times of the year. Young shoots and buds of all kinds, beechmast, acorns, hazel nuts, walnuts—almost any nuts, in fact—besides wild and cultivated fruits of many kinds, are eaten when the opportunity occurs.

The questions of winter food-stores and hibernation of squirrels in this country appear to be very uncertain. It is generally stated as an accepted fact in many natural-history books that the squirrel makes a store of seeds and nuts in a hollow tree during the autumn, then retires for his long winter sleep, only awaking at long intervals for a brief period of feeding. How such a fairy story has arisen it is difficult to say, but so far as actual observed facts go the squirrel does not appear to make large centralized food-stores, nor to hibernate for any lengthy period. The only vestige of food-storing actually observed is the autumnal practice of burying isolated nuts close to the trees from which they were gathered, and on very few occasions have squirrels been known to show

[1] More complete and detailed information regarding the American grey squirrel, the decrease of the red squirrel, and the inter-relations of the two species, will be found in 'The Ecology of the American Grey Squirrel in the British Isles', by A. D. Middleton. (*Proc. Zoological Society of London*, 1930, pt. 3, pp. 809–43.)

any signs of remembering where they had buried these 'food-stores'. As for hibernation, the only British mammals concerning which this term can legitimately be used seem to be the dormouse, hedgehog, and bats. All naturalists who observe nature instead of writing about it agree that squirrels are active throughout the whole year. Certainly they are less active during the winter (and so are naturalists), but during the most severe frosts, or with snow-covered ground, they have frequently been seen about, actively searching for food. I saw one busily foraging a hedge and some trees in Cumberland, with snow falling heavily and the temperature low enough to make any human want to hibernate as quickly as possible. It is, of course, probable that they sleep for periods of two or three days during very severe weather.

Of the above feeding-habits, by far the most important from the forester's point of view is that of peeling the bark of young conifers. From the middle of May until the end of July, when the sap is actively rising, the red squirrel strips the outer bark and eats the inner sap-bearing bark on the 4–10-year wood of the main stem or branches, often completely girdling the tree, and in any case removing large patches of the bark. Scots pine is the species most subject to this form of damage, but both European and Japanese larches have been similarly treated on many occasions. Peeling is usually confined to trees of from 12 to 25 years of age. When the tree is completely girdled about 5 to 10 feet from the top, the crown dies and is generally blown off in a subsequent gale; a lateral leader is then formed—or two or three laterals may make equal growth—resulting in a distorted tree that can never be of much value as timber. In the case of 'patch peeling' the top usually continues to grow, and in time the bark closes up over the wounds, but in such cases a permanent and deep-seated scar is found in the mature timber at the point where the peeling took place. Many foresters hold that this 'patch peeling' is far more troublesome than the distortion caused by ringing, as distorted trees can easily be removed in thinnings. The number of trees patched is much greater as a rule than those ringed, hence all cannot be dealt with in thinnings, and their identification is also not always easy. It is frequently not the grower of this timber who experiences the loss, but the buyer, who purchases a stand of Scots pine and then finds that a large proportion of his planks are faulty.

From 1900 to 1920 the damage caused by peeling Scots pine in the north of Scotland must have represented a net loss of thousands of pounds on every estate with large areas of timber, but it has been impossible to get any accurate estimate from different estates of the direct financial loss involved. In 1929, actual counts over a transect through a stand of 35–40-year Scots pine at Kirkhill Forest, Aberdeenshire, showed that 30 per cent of the trees were distorted through squirrel damage calculated to have taken place between 1910 and 1920. This plantation had been thinned once, and presumably a large percentage of the thinnings would be damaged trees, and it was not chosen as an exceptionally bad area for squirrels. On Speyside the foresters estimate that 50 per cent of the trees in many plantations were badly damaged during the period 1900–20. Assuming that about 60 per cent of the damaged trees

will be eliminated in future thinnings at Kirkhill, a very conservative estimate of the possible mature crop destroyed would be 10 per cent. Taking the ultimate value of this timber at £150 per acre, an average loss of £15 per acre is quite probable on a normal Scots pine rotation, without taking any account of the money expended in protective measures, and the loss on account of depreciated thinnings.

Complete data on this subject have not been obtained from every part of the British Isles, but it seems certain that peeling has always been much more intensive in the north of Scotland than elsewhere; it has occurred in practically all parts of the country at one time or another, but in southern Scotland and England there does not seem to have been anything approaching the damage in the north. Many parts of the New Forest, Hampshire, experienced extensive peeling when squirrels were very abundant, both Scots pine and larch being attacked. From the evidence available, there is no ground for the belief that peeling is a local habit, confined to squirrels in any particular parts of the country, but the extreme damage in northern Scotland is probably due to limited choice of food in pure pine forests. Most of the southern woodlands are mixed, and offer a wide selection of foods for squirrels at all times of the year, especially in the summer months—when the practice of peeling is so widespread in the pure coniferous areas.

Compared with peeling, the other ravages of the red squirrel occupy a minor position, but there is little doubt that the amount of seed eaten must significantly affect natural regeneration of Scots pine, and interfere with the available crop where seed is collected. On the other hand, the squirrel probably aids the regeneration of pines, oak, and beech to a limited extent by its habit of burying seeds and nuts. The practice of eating buds and shoots of various species in the spring must do damage to trees, especially when the leading shoots of young conifers are bitten off. In stands of mature timber, of course, the squirrel can be neglected without much risk, unless natural regeneration or seed-collection is desired, but in young plantations up to about thirty years of age, a few squirrels can do an enormous amount of permanent damage in a very short time, and in such circumstances it would seem well worth while for the forester to pay more attention to a pair of squirrels than to a whole herd of deer.

The depredations of the American grey squirrel have not received so much attention from the forester as those of the native species, because the area so far covered by this alien does not embrace many of the major forestry areas, such as northern Scotland. Its apparent preference for deciduous woodland also tends to make it less troublesome to the forester at this time when the majority of plantations are coniferous. Like the red squirrel, the principal crime of the grey, so far as forestry is concerned, is its habit of peeling young trees. But the records, to date, of grey-squirrel peeling have been confined to hardwoods: sycamore and beech are the favourite species, but oak, maple, chestnut, and birch are attacked in the same manner. Ten- to twenty-year-old sycamores are very severely dealt with by grey squirrels in many parts of the

country where these animals have become numerous; up to the present there appears to be no evidence of peeling of conifers, but the grey squirrel has been found to do extensive damage in some areas by biting off the leading shoots of young spruce and larch. In its taste for seeds, nuts, and fruit the grey differs little from the red, but as regards eggs and young birds it is undoubtedly a much more serious offender than the British squirrel: the effects of a large population of grey squirrels upon the insectivorous birds may become of serious importance to both forestry and agriculture. Although the grey squirrel hardly seems likely to become such a specific pest to forestry as the red, it undoubtedly has a much wider range of activities, and deserves the determined condemnation of forester and agriculturist alike.

Squirrels, both red and grey, are not easy animals to control. They are very secretive and difficult to see, especially in a thick plantation, and there need not be many squirrels to cause much damage. Fencing—the safeguard of the forester against all other mammals—is of no consequence to squirrels, and trapping is rarely possible on a large scale. Shooting, therefore, is practically the only means available for keeping down the numbers, and every forester knows the difficulty of keeping plantations clear of squirrels by this method. A good terrier which will 'mark' a squirrel in a tree is the most effective anti-squirrel measure yet discovered, and every dog of this kind in the possession of a forester or gamekeeper is a real asset to any estate where timber production is considered.

On many estates it is the duty of the gamekeepers to deal with squirrels, the forester often not even being in possession of a gun. This principle is not a very sound division of labour, as the keeper usually has so many other things to look after that he can rarely give squirrels the attention they merit. A 0·410 shot-gun in the possession of a forester is a most handy means of accounting for large numbers of squirrels in the ordinary round of duties, especially if accompanied by a good squirrel-hunting dog.

A trap which has been found to be very effective for grey squirrels, but which does not appear to have been tried for the reds, is a simple wire cage, about 3 feet by 2 feet, with a 'sleeve' entrance at one side, constructed so that squirrels can readily find their way in but have difficulty in seeing the proper way out. This trap requires very little attention, being merely baited with corn and visited daily; in addition to its simplicity it has the advantage that any animals or birds caught accidentally can either be released or summarily dealt with by the trapper.

Poisoning would, in most cases, be impracticable for squirrels owing to the impossibility of ensuring its application to squirrels only. The question of using a specific virus to spread disease amongst them has not been investigated and would involve considerable research, but it is a method which would seem to be ideal for squirrels in common with many other rodent pests.

THE RELATIONSHIP BETWEEN FROST DAMAGE AND LARCH CANKER

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WITH PLATES III AND IV

INTRODUCTION.

IT is probable that the larch canker disease is regarded by most foresters in Britain as being no longer a source of much danger. Silvicultural experience has shown that by careful choice of site and proper tending, larch plantations may be raised in which the losses due to canker are negligible. It is unlikely that the severe losses which were sustained in the past, and which caused the European larch temporarily to go out of favour as a forest crop, will ever recur.

Nevertheless as a problem in forest pathology it cannot be claimed that this disease is fully understood. It has never, for example, been demonstrated in what manner the fungus enters the host and causes canker development to begin. All that is known is that a canker may develop if a piece of material infected with the larch canker fungus (*Dasyscypha calycina* (Schüm.) Fuckel) is inserted into a larch stem (2, 3, and 4). It is deduced that the fungus must be the cause of canker development in nature. Robert Hartig (2), who was the first to demonstrate this, and to prove the parasitical power of the fungus, assumed that in naturally infected trees, as in those artificially infected, mechanical wounds provided the means of entry for the parasite. Wounds due to snow break, insect damage, or damage in planting are typical examples. This view was the one generally accepted until Hiley (3) re-examined the whole question. As the result of an extensive investigation he came to the conclusion that wounds are not associated with the origin of most cankers. This created a difficulty, for inoculation experiments have shown the fungus to be entirely a wound parasite. Hiley overcame this difficulty by enunciating the hypothesis that infection takes place usually from a dead branch or dwarf shoot which the fungus had colonized as a saprophyte. Any one who has examined a number of larch cankers must have been struck by the extent to which this is a satisfactory hypothesis. In this country it may be said that this is the accepted explanation of the manner in which infection takes place and the hypothesis has received favourable notice from continental authors (1 and 4). The publication of Hiley's work marked a definite stage in the development of research into the larch canker disease. Other extensive reviews of this disease have been published since (1 and 4), but in neither case has any advance been made in regard to this essential point.

That it might be possible to question the parasitical powers of the fungus occurred to the author after examining small frost cankers on Douglas fir. In

their amphitheatre-like development the frost cankers were exactly similar to larch cankers. The chief difference between them lay in the presence of frost rings in the wood, and the obvious connexion between the frost rings and the dying-back of the cambium. The question 'Is frost ever the principal factor in the development of larch canker?' naturally suggested itself. When larch canker was first discussed in the middle of the last century, the answer would have been 'Yes' (1), but with the passing of time, frost, even as a cause of wounds through which the fungus may enter, has come to be discountenanced (3 and 4). It has never been questioned that larch can suffer from frost damage, all that is doubted is the importance of frost as a direct cause of canker or even of wounds through which infection might enter. This doubt is based chiefly on the seasonal development of cankers because hitherto it has always been assumed that this takes place in the winter (3). In proof of this it is stated that the cambium dies after one annual ring has been formed and before another has begun to develop. The proof thus depends upon a deduction based on the anatomy of the cankers rather than upon observation of actual cankers in course of development.

In spite of this anatomical evidence of the winter development of cankers, one striking feature of past research into the larch canker disease is the neglect to study comprehensively its abnormal anatomy. Hiley (3) seems to have been the first to pay serious attention to this. He describes accurately what is usually to be seen. Within the canker the cambium dies at a time when the wood of one annual ring is completely formed but that of the next has not yet even begun to appear. This period, it is assumed, is the winter. A complete annual ring is formed during the season before the canker begins, but abnormal tissue is to be seen at the very beginning of the spring wood. This abnormal tissue starts as lignified wood parenchyma, from which the cell contents have usually disappeared. As the annual ring develops the tissue gradually becomes more normal in type until at length fully normal tracheids are formed. Within this abnormal tissue both normal and irregular resin ducts are to be found. As the cambium dies back year after year abnormal tissue of this type is formed in the spring wood on either side of the canker.

The weak point in the evidence of the winter development of cankers is that no one appears to have attempted to determine what is the period during which the cambium is not laying down new wood cells and thus is in a resting condition. When the seasonal growth of the larch in north-western Europe is considered it can be seen, however, that this is a most important matter. The two outstanding features to be remembered here are, firstly the long growing-season of the larch, and secondly the periods during which early and late frosts occur. The larch in Britain flushes at any time from about the end of February to the middle of April, depending on the latitude and altitude of its locality: it ceases growing about the end of September to the beginning of October. The period of danger from late frosts is not really over until the middle of May or the beginning of June, and that from early frosts may start as early as the middle of September. It follows that both in the spring and the autumn there

are periods within the growing-season of the larch during which frosts are liable to occur: indeed it may be said during which frosts usually do occur. That frost damage actually occurs during these times is of course well known, but the extent of this damage has probably never been fully appreciated. The most obvious type of frost damage is the killing of the leaf, and the defoliation so caused may be serious and not unrelated to canker development in that the vitality of the tree is lowered. An equally serious form of frost damage is injury to the cambium, phloem, or cortex of the shoot or branch. This type of injury is not so obvious. Its importance has either been definitely discountenanced, or when admitted has been referred to in very general terms. Under these circumstances it seems to be desirable to determine, if possible, what exactly is the importance of frost damage, both in the form of defoliation, and of injury to the stem, to the development of the larch canker disease. As a preliminary to the experimental production of frost damage an investigation is being made into the condition of larches growing in areas known to be subject to severe spring frosts. The investigation naturally falls into two parts, namely, injury to leaves, and injury to stems. The present paper will be confined to frost injury to stems and especially to the development and anatomy of frost cankers. The chief place from which material has been collected is Bagley Wood, near Oxford.

THE FROST RING AS A DIAGNOSTIC FEATURE.

In order to determine whether or not a canker is caused by frost, it is necessary to have certain diagnostic features. This is one of the difficulties in the diagnosis of frost damage, because very little is really known as to what is to be looked for in an injured stem. The bark of a stem, if killed by frost, is soon colonized by fungi, and within a short time it may be quite impossible to tell whether or not these are the cause of death. If death is not observed to coincide with some particular frost, the true cause of disease cannot be determined in many instances, unless in the adjacent still-living parts some type of abnormal tissue is to be seen which is typical of frost damage. Perhaps the only easily recognizable tissue of this type is the frost ring. This is a phenomenon which has been described in detail a number of times (5) and is well known. It develops in the wood when the actively dividing cambium is subjected to a sufficient degree of cold to upset the normal development of the cells but not to kill them. In a conifer, instead of normal tracheids, wood parenchyma forms which almost always becomes lignified but for some time retains its starch content. This zone of parenchyma is followed by a more or less irregular zone of abnormal tracheids, and these in turn gradually give way to entirely normal wood. The extent to which the abnormal tissue forms is very variable. In a very slight frost ring nothing more may be seen than a zone of collapsed tracheids with slightly swollen cells in the medullary-ray parenchyma: when the frost damage has been severe great rents may be formed in the tissue, and these are usually filled up with parenchyma resembling in appearance tyloses in a vessel of a broad-leaved tree. It seems to be quite certain that in some

instances a small area of the cambium may be killed while the cortex or phloem opposite remains alive, there being few, if any, obvious signs of injury on the outside of the stems.

Resin ducts do not occur in frost rings unless some part of the cambium has been killed. They are then present in the vicinity of the wound, but usually cease to be formed an inch or two away from it. The extent to which a frost ring occurs depends on the extent to which the cambium has been active, on the intensity of the cold, and on the position of the cork cambium. When the latter has begun to form deep in the cortex, and so causes production of thick rough bark, stems usually cease to be susceptible to frost injury. It is thus only the younger, smooth-barked parts of a tree that are usually susceptible to frost damage, and because of this, the discussion that follows will only deal with the smaller cankers. The development of the later stages of a large canker cannot be satisfactorily investigated by a purely anatomical method.

THE SEASONAL SUSCEPTIBILITY OF THE CAMBIUM TO FROST.

The cambium of the European larch, as of all trees native to a climate in which regular seasonal frost occurs, is susceptible to injury by frosts only during a limited period of the year. This period is usually thought of as the time during which the cambium is actively producing new cells, and is commonly referred to as the growing season. At any other time, when no new cells are being produced, the inference is that the cambium is in a hardy frost-resistant condition. Now with regard to the larch at least, this inference is not necessarily true. There is a certain period in the spring during which the cambium has changed from the winter resting condition, but in which no apparent production of new cells takes place. This period probably coincides with the time when the dwarf shoots have flushed, but in which no development of long shoots has taken place. It is of at least a month's duration, varying from tree to tree according to variations in individual periodicity of development. It begins sometime in the latter part of March, and finishes towards the middle of May. It is possible that a similar period occurs in the autumn, but there is no evidence of this so far, and it has not yet been possible to test the matter experimentally.

The beginning of this early period of susceptibility not only varies from tree to tree, but it also varies in different parts of the same tree and sometimes at different sides at any one point of a particular stem. The time of its termination varies similarly and is much more easily observed. Thus new wood is very commonly formed first on one side of a shoot, or around a dwarf shoot, or at the base of a leading shoot, and a certain period occurs during which the new wood may be restricted in extent round such points. This period when the cambium is sensitive to frost, but has not yet formed new cells, is of importance in the investigation of larch canker because in certain instances it becomes impossible to decide by an examination of the anatomy whether the cambium died during the autumn, winter, or spring. This is illustrated by Figs. 1 and 2. Fig. 1 shows the cambium in a small uninjured branch collected on 18 October 1927.

Fig. 2 is from a similar but somewhat larger branch collected on 25 April 1928. It will be noted that there is no essential difference between the state of development of the cambium in these two sections: even in the middle of May it is not difficult to find stems that have laid down no new fully expanded lignified wood cells, and in such cases it may easily be assumed that the last tracheids to be formed were those of the previous autumn.

In the field, the killing of the cambium during this early period is a frequent occurence after sevęre April frosts. Stems so affected are most easily identified if examined within a short time after the frost. Small twigs may be affected in great numbers, and be entirely or partially girdled. Their bark is usually killed over a small area, not more than an inch or two long, and including a dwarf shoot in its centre, and if the bark is examined no fungus mycelium is to be found within it.

FROST RINGS AND THE SEASON OF THEIR DEVELOPMENT.

The early period of susceptibility that has just been discussed is distinguished as not being a time during which frost rings develop. Frost rings are associated with the actively dividing cambium, and they can only be caused during the period when new wood is forming. In the centre and south of England the months of June, July, and August are usually free from severe frost, and the formation of frost rings is confined to the end of April, May, September, and possibly the very beginning of October. In certain localities, however, frosts during June are by no means infrequent, and possibly they may even occur at other times during the summer. In general the spring frosts are the most frequent and dangerous and the greater part of the frost damage of trees appears to occur at this season.

Frost rings may, of course, be found in stems outwardly uninjured. It is quite common to find them in a stem for three, four, or more years in succession, depending on the seasons, and also the rate of growth of the stem, because frost rings cease to be formed in European larch after the phellogen forms deep in the cortex and the stems become rough-barked. Provided that the rate of growth of the annual ring in relation to the season of the year is approximately known, the date of the frost which caused any particular ring can be determined in many instances to within a week. Thus Fig. 7 shows frost rings in four successive annual rings (1926–9) in the stem of a European larch. In 1926 the ring was a slight one, consisting chiefly of collapsed cells. It developed after a wide zone of normal wood had formed and was probably caused by a frost on 9 May, the coldest morning of the month at Oxford in that year. In 1927 the ring is much more severe. It has obviously developed earlier than the previous one, for only one or two rows of normal tracheids had formed before it. This ring is associated with the severe frost of 30 April and 1 May 1927. The 1928 frost ring is of similar severity to that of 1927, and as in 1926, this ring only developed after a considerable zone of normal tracheids had been formed. This ring coincides with the frost of 12 May 1928. In 1929 all that is to be seen of the frost ring is a slight development of irregular-shaped tracheids at the very

beginning of the annual ring. Lower down the stem this ring becomes broader and similar to the one shown for 1927. This variation in development in different parts of the same stem is caused by the different state of the cambium at the respective places. At the point shown on the section, the cambium had only just begun to form new wood, whereas lower down at least one or two rows of new tracheids had been already cut off on one side of the stem. This 1929 ring might have been caused by a frost on 21 April or by one on 2 May. The frost on the latter date is the more probable.

The actual temperatures in Bagley Wood, where this tree grew, are not known for the four years in which these frosts occurred, but by comparison of temperatures taken during the last year (1929–30) with those recorded at the Radcliffe Observatory, it is known that the movements in temperature coincide, and if there is a difference in temperature between the wood and the Observatory, the wood is nearly always colder. Thus a warm night in Oxford is always a warm night in Bagley Wood and vice versa. This being so the minimum grass temperatures at the Radcliffe Observatory give some idea of the severity of the frosts in Bagley Wood on the dates above mentioned. The temperatures are:

9 May 1926	27·7° F.
30 April 1927	18·5° F.
1 May 1927	21·9° F.
12 May 1928	22·9° F.
21 April 1929	19·4° F.
2 May 1929	22·7° F.

All the temperatures, except that on 9 May 1926, are known by experiment to be sufficiently low to cause external damage to European larch on the dates given, and it may be taken, therefore, that they are sufficiently severe to cause frost rings to form.

FROST RINGS AND FROST CANKER.

One of the great difficulties in the study of larch canker is to find any criterion by which it may be determined whether the cause of the disease is frost or fungus. It is obvious that in the smaller cankers the frost ring is of very great value, for its presence plainly indicates that the tree grows in a locality subject to severe frosts. If, moreover, the frost ring is connected with the canker it may be possible to show that the cause of the death of the cambium is frost and not fungus. This is a very important point, for once an open wound has been formed, from whatever cause, the dead remains of the bark in it are speedily colonized by the larch canker fungus, which for lack of further evidence is taken to be the cause of the trouble. The canker shown in Fig. 3, for instance, bore fructifications of the larch canker fungus and had abundant mycelium in the dead tissues. To outward appearance it was a canker caused by the parasitic action of the fungus. Actually it is a frost canker and this can be demonstrated. The section shows that part of the cambium was killed for

three years in succession, namely, in 1925, 1926, and 1927. In the first two years the wound healed over, but in 1927 an open canker was formed. A frost ring can be seen in the wood formed during that year, but in the two previous years no ring was formed and all that can be seen is a little abnormal tissue on either side of the wound. In 1927 the frost ring was caused by the frost of 30 April which also killed the cambium. The death of the cambium in the two previous years is also to be attributed to frost and the abnormal tissue on either side is partly frost tissue and partly traumatic tissue.

It is not, of course, obvious that it is correct to interpret the injury in 1925 and 1926 as frost damage. Actually this is the type of injury always caused when the cambium is killed by frost during the early period of susceptibility before the new wood forms, but after the dwarf shoots have flushed. In both these years, frosts of sufficient severity to cause this type of injury occurred during this period, viz. on 4 April 1925 with a minimum grass temperature of 17·7° F., and in 1926 on 31 March when the temperature was 22·5° F. at the Radcliffe Observatory. A detailed examination of the canker gives further evidence showing that frost was the cause of death in those two years and moreover demonstrates clearly some of the types of abnormal tissue to be found in frost cankers.

If the outer annual ring is examined it will be seen that there are two distinct zones of abnormal tissue (Figs. 3 and 4). The less obvious one lies immediately at the beginning of the annual ring: it only extends part of the way round the ring, is intermittent in that part, and consists entirely of parenchyma. The second zone is the frost ring already mentioned. This lies eccentric to the previous annual ring, and is quite distinct from the inner zone. In contrast it consists of two types of tissue, namely abnormal resin ducts, or masses of parenchyma which are obviously attempts to form these, and simple parenchyma (Fig. 4). The latter may be irregular in shape or may consist of cells which in cross-section are much the same shape as normal tracheids. Where the frost ring touches the previous annual ring (Fig. 3), it consists of an intermittent row of parenchymatous cells only, and the inner zone of abnormal tissue has then entirely disappeared. The difference between the two zones lies chiefly in the occurrence of resin ducts in the outer, and in the failure of the inner to encircle completely the annual ring. If a section is taken an inch and a quarter lower down the stem, and definitely outside the canker, the two zones again appear and they both consist entirely of parenchyma. It is to be noted that here the outer one fails to encircle the annual ring, and that the inner is still more restricted than before. Another inch and a quarter further down still, the inner zone has entirely disappeared, and all that remains of the outer one, that is the frost ring, is an intermittent zone of parenchyma lying at the very beginning of the annual ring, and similar in all respects to the inner zone nearer to the canker.

Abnormal tissue such as this, which extends in zones for some distance up and down a stem, must have arisen as the result of injury to the cambium at a certain time over the whole length of stem affected. Moreover, the position

of the zones marks the date at which the injury occurred; the inner zone must therefore have developed earlier than the outer one. Further, if the development of these zones of abnormal tissue shows that the cambium was capable of injury at the time of their initiation, their failure to encircle the annual ring completely must show that part of the cambium was not susceptible to injury at that time. This is especially clear in the case of the outer zone, which encircles the annual ring at one point, thus showing that the influence which caused it to develop acted on all sides of the stem. It is plain, moreover, from the eccentricity of the outer zone and its gradual disappearance lower down the stem that the formation of new wood did not begin uniformly over the whole stem, but that on one side and at certain places, such as at the canker, it began earlier than elsewhere. From this it may reasonably be inferred that the change from the hardy winter to the susceptible spring condition also took place locally, and as a matter of fact this can be proved experimentally.

It has been seen that anatomically the two zones of abnormal tissue are essentially the same in character, the chief difference being the presence of resin ducts in the outer zone. The presence of the resin ducts only at the edge of the canker and the occurrence of them in a frost ring only when it is connected with a wound, show them to be traumatic in character. Their presence in the outer zone also points to the fact that the cambium died at the time this was initiated, and a section of the dead tissues in the canker shows it to be in exactly the right position (Fig. 5). The newly formed tracheids were unlignified at the time of their death, and those fully expanded lie three to five deep. It is clear from this that the cambium died in the spring, and as it stands on the same horizon as the frost ring, frost was the cause of its death. The rents in the bark are also typical of frost cankers and provide further evidence that frost was the cause of death. On account of its essential similarity to the outer zone, the inner one must also be regarded as being caused by frost, and its position also shows that it also must have formed in the spring but at an earlier date and during the early period of susceptibility before the formation of new wood had begun. The failure of this zone to encircle the annual ring is confirmation of the deduction made previously that the cambium not only began to form wood on one side only but that it also changed from a frost-hardy to a frost-sensitive condition on that side.

From what has been said above, it will be seen that when a cambium develops eccentrically to the previous annual ring, a time always occurs when it is susceptible to injury by frost on one side only and, moreover, it may be killed on this particular side over a very restricted area at a time when no new wood cells have expanded. At such a period the only reaction to the frosting is the development of traumatic resin ducts in the immediate vicinity of the wound and some slight frost tissue, such as a row of parenchymatous cells, at the beginning of the annual ring. This is exactly what is to be found in the 1925 and 1926 annual rings in the canker now under discussion, and it has been seen that in the spring of these years frosts occurred of sufficient severity to have killed the cambium. The next canker to be examined began in 1925 and in

that year shows an exactly similar reaction, and indeed in many cankers this is the common type of abnormal tissue to be found.

The type of canker which has just been examined is exceedingly common on the smaller stems and branches of European larch growing in localities subject to severe early and late frosts. Frost rings may or may not appear in them for the reasons already stated. If such a canker should be situated on the main stem it commonly forms the beginning of a large canker. In such cankers which begin when the stem is very small, frost rings can often be traced for several years in succession until the stem is no longer susceptible to spring frosts. Fig. 6 is an example of what would probably have been the centre of a large canker if the stem had not been completely girdled. On this canker fructifications of the larch canker fungus were found scattered over the dead bark. The cross-section shows that the canker died back for three years in succession. In this canker the abnormal tissue is often confused, but at least ten frost rings or parts of frost rings can be distinguished although not all of them can be pointed out on the photograph of the section.

The number of distinguishable frost rings and the probable dates of the frosts that caused them are shown on the following diagram (Text-fig. 1).

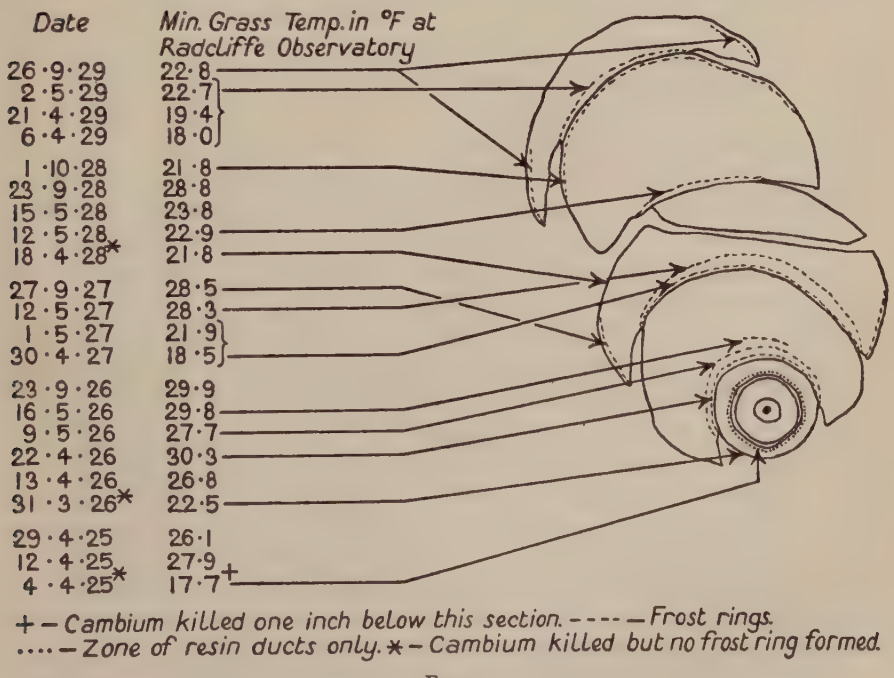

FIG. 1

In 1925 the cambium died before new wood had formed, and a zone of resin ducts is the only abnormal tissue seen. The same happened in 1926, but three frost rings subsequently appeared, that of 9 May being the most severe. None

of the frosts causing these rings caused the cambium to die back further. In 1927 the very severe frost of 30 April undoubtedly caused further dying-back, and in the spring wood a later but much slighter frost ring appears. In the autumn of 1927 the cambium was still further cut back. The frost causing this occurred at the end of the growing-season and caused typical and easily distinguishable rents in the bark and summer wood. In the spring of 1928 at least two severe frosts affected the cambium. Its further die-back is probably due to the first, on 18 April, while the second, on 12 May, caused the development of the severe frost ring. In the autumn of 1928 the cambium again died back, and just below this section was girdled. The typical rents in the edge of the annual ring can be seen in the section. The severe frost on 1 October is to be associated with this. In 1929 two frost rings appeared. In the spring there is a severe one caused by the frost of 2 May and in the autumn a very slight one, appearing only at the ends of the ring and probably caused by a frost on 26 September.

Not all the frost rings here noted can be traced up or down the stem from the canker. Twelve inches above its centre and over nine inches above its upper edge the frost rings of 12 May 1928, 12 May 1927, 30 April 1927, and 9 May 1926 can be seen, and the ring of 12 May 1927 only appears at two or three points as a short line of abnormal tissue. Five and a half inches above the edge of the canker, in addition to these rings, that of 2 May 1929 just appears as a very slight intermittent zone of abnormal tissue lying at the very beginning of the annual ring (Fig. 7). Still further down and two inches above the edge of the canker additional rings still appear, namely that of 22 April 1926 as a very slight partial ring and a new partial ring in 1928 which is to be attributed probably to the frost of 18 April 1928. This frost ring is not seen elsewhere. Also, at this level the ring of 2 May 1929, although still incomplete, is for the most part plainly visible, and at one point the cambium was killed on this date (Fig. 8). On account of this, traumatic resin ducts appear in the ring.

It is thus seen that the nearer the canker is approached from above, the more numerous do the frost rings become. Thus the following numbers of complete or partial frost rings appear at the different levels:

12 inches above the canker centre	4 frost rings
8·5 „ „ „	5 „ „
5 „ „ „	7 „ „
at the canker centre	10 „ „

If the stem is investigated below the canker the frost rings again decrease in number. Thus five and a half inches below the centre of the canker only three frost rings can be seen, namely those of 9 May 1926, 30 April 1927, and 12 May 1928. At this point there was only a very slight and incomplete development of the annual ring in 1929 owing to the stem having been girdled at the centre in the autumn of 1928. As in the first instance examined, so it is apparent in this that the stem is more susceptible to frost damage at the point of the canker than elsewhere. There are two possible explanations of this. The first

applies especially to cankers situated on the main stem of a tree and only a short distance above soil level, as in this instance. It is that the temperature was probably lower at this point, which was at about the level of the tips of the coarse ground vegetation, than elsewhere. The second, which applies generally, is that the cambium became active, and thus susceptible to frost, at this point before any other investigated. Direct evidence of this is supplied by examining the width of normal wood formed before any of the later formed frost rings developed. The frost ring of 9 May 1926 is of most service in this respect, because it was very slight and leaves the underlying tissue very little distorted. If the number of tracheids formed before this frost ring developed are counted at various points up the stem and a curve drawn, a very clear picture is obtained

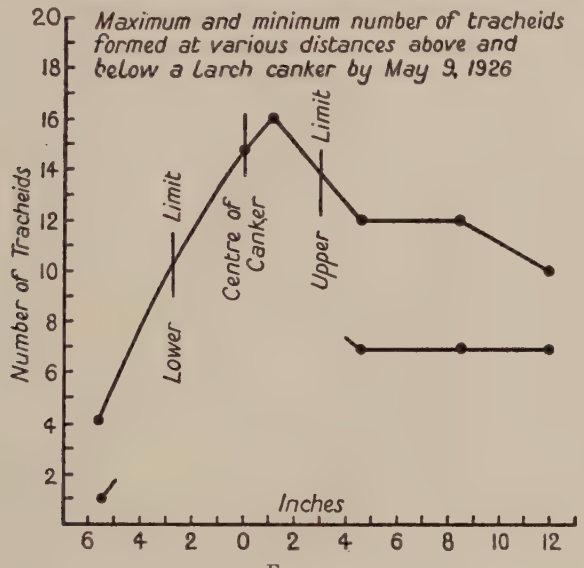

FIG. 2

of the amount of normal wood formed over the length of stem investigated. Text-fig. 2 shows two such curves, one for the number of tracheids formed at the widest part and the other for the narrowest part between the frost ring and the previous annual ring. The latter curve is incomplete because the 1926 annual ring is broken in the canker. The complete curve shows that at the time the frost ring of 9 May 1926 was formed many more rows of tracheids were laid down in that part of the stem affected by the canker than elsewhere. This tendency of the cambium to become active first at the point of the canker was seen in the first case examined. It is a point of great importance, for it is obvious that the earlier the cambium becomes active the greater will be the period during which it will be liable to frost damage.

Frost cankers occurring on the main stem could be multiplied indefinitely. Only when the stem is small is there any real danger of it being girdled. In the typical canker the stem is only partly girdled at first and then the edge of the canker is cut back year by year. It is clear from this that the edges are points of

particular susceptibility and liable to be killed when the cambium further removed is no longer in any special danger. This is illustrated in the next canker to be discussed (Fig. 9). This was a stock demonstration canker at Oxford, and it is not known at what date it was collected. The frost rings cannot, therefore, be correlated with any particular frosts. This canker died back for six years in succession. The frost tissue is exactly similar to that seen before. In the year before the canker started, and in the autumn of the second year, and the spring of the fourth year of canker development, very distinct frost rings are to be seen (Fig. 10). No frost tissue developed in the last ring and in the remainder it lies directly at the beginning of the respective annual rings encircling them to a greater or less extent. In the dead bark the rents so typical of frost-killed phloem occur, and the irregular fragments of dead bark on the outside of the stem (Fig. 9) are at least partly caused by frost. It is characteristic of frost cankers that where a frost ring lies at the very beginning of the annual ring and only partly encircles it, the most severe part of the frost ring is at the edge of the canker. This can be seen in the first and second year of this canker (Fig. 10), and it may be noted that the most severe part of the frost ring in the year previous to canker formation is on the side where the canker developed later. It is plain that as a stem grows bigger and beyond the size when it is susceptible to damage by early or late frosts, the edges of the canker are the only possible places open to injury.

When this stem was examined about half an inch above the upper limit of the canker the chief frost rings were found. It is interesting to note, however, that the frost ring in the fourth year of canker development was not nearly so broad as at the centre of the canker; and secondly that the narrow band of the outer annual ring does not appear at all, showing again that cambial activity begins earlier within the region of the canker than in the stem outside it.

So far all the frost rings discussed have consisted chiefly of a zone of parenchymatous cells which sometimes were much the same shape as a tracheid in cross-section but which usually were rather irregularly shaped or roundish, and in cross-section much larger than the ordinary tracheid. It is sometimes noted that mixed in with this type of cell are a few others, rather narrow, oblong in cross-section, and having the appearance as if their development had been arrested when not long cut off by the cambium. This narrow type of cell in cankers is often met with and together with resin ducts may be almost the only type of abnormal tissue present. This is the case with the canker shown in Fig. 11. The section through the canker shows a slight frost ring in the spring of 1921 (the second annual ring formed). The canker began in 1923 and continued to develop until 1926, in the summer of which the tree was felled. No frost rings developed, although at the edge of the canker short dark zones of abnormal tissue occur: these consist chiefly of resin ducts. Only in 1924 is there a complete zone of abnormal tissue, and this lies immediately at the beginning of the annual ring.

A typical piece of cambium from the dead tissue gives little or no sign of development, but sometimes it can be seen that the first row of tracheids was

just expanding at the time of death. In 1924 (Fig. 12) this stage had hardly been reached, and the dead tissue shows nothing but a line of narrow cambial-like cells. Adjoining this dead tissue is a short line of resin ducts, but as the resin ducts gradually cease the line of abnormal tissue is continued by a zone of cells which in shape resemble those in dead cambium (Fig. 13). These cells are abnormally shaped tracheids showing the arrested development already referred to. A little further on, this type of cell becomes mixed with irregularly shaped and swollen cells, some of which are tracheids and some parenchyma (Fig. 14). If the last three sections are compared the continuity of the zone of abnormal tissue with the dead cambium can easily be seen and, except where the swollen cells occur, there is no doubt that this zone represents the state of development of the cambium, or perhaps rather of the tracheids newly split off, at the time the cambium was killed. That this was the spring is shown by the position of the zone at the beginning of the annual ring. There can be no doubt that this zone of tissue is a frost ring, formed in the spring at the time when the cambium was killed and the canker was developing. The forester in charge of the plantation where this tree grew records that from 1923–5 inclusive the trees were largely defoliated by April frosts. There are, however, no actual temperature records of the frosts in this plantation, which was situated in the valley of the Torridge, north Devon, on a steep hillside with an easterly aspect. The terrible condition of many of the trees and the innumerable cankers on the side branches left no doubt, however, of the severity of the conditions experienced.

This last canker is important because it demonstrates that when the cambium is killed in the spring no very extensive abnormal tissue need be developed in the adjoining living parts even although frost is the cause of death. This restricted development of abnormal tissue has already been considered and has been shown to be due either to the cambium being sensitive to injury over a restricted area, or to its being protected by the development of thick rough bark. In this instance development of a complete zone of abnormal tissue in 1924 shows that the restriction of the abnormal tissue, in most years, is related to the state of the cambium only. While no attempt is made here to analyse the later development of large cankers, it is clear that severe early spring frosts are not to be excluded as a cause of their continued growth. Also the non-occurrence of such frosts or the development of some protection from them may account for the healing of such cankers. This may frequently be noted, not only in trees that have renewed their vigour for some reason, such as increased space for crown development, but also where it is obvious from the extreme and continuing narrowness of the annual rings, that the conditions for growth have been unfavourable during the whole period of healing.

It is not always realized how frequent and severe are the frosts in this country during the period when the European larch is in a susceptible condition. Recent measurements have shown that the minimum grass temperature at the Radcliffe Observatory, Oxford, corresponds very fairly with the air

temperature up to four metres from the ground in the plantation from which the first canker was taken. If the lowest minimum grass temperature at the Radcliffe Observatory is taken in each year from 1892–1929 these minima can be arranged as follows:

Month	Number of times from 1892–1929 that the lowest min. grass temperature at the Radcliffe Observatory was:		
	At or below 20° F.	*Between 20° and 22° F.*	*Above 22° F.*
March .	20 (10)	13 (7)	5 (3)
April .	13	9	16
May .	0	3	35

The figures in brackets show the number of times the lowest temperature occurred on or after 15 March, which, on the average, is probably the time when the larch begins to be susceptible to frost injury. Experiments now in hand show that the critical temperature for frost damage to the European larch lies somewhere between 20 and 22° F. It can be seen from the above table that in the latter half of March the temperature was at or below the critical point in 10 years out of 38, and in April for 13 out of 38. It is known, however, from observations in the field that injury occurred in years when the minimum grass temperature in Oxford was as high as 22° F. Thus in well over half the years since 1892 the temperatures have been low enough to cause injury. When it is remembered that here only one day in each month has been picked out, and that severe frosts in one month do not always occur in the same year as those in other months, it will be seen that in the part of Bagley Wood referred to the chance of European larch being injured by frost year after year is very great. As a matter of fact well over 90 per cent of the trees in this plantation, which is quite young, were badly cankered on the main stem and all were so affected on the branches.

It may finally be noted that all trees are not equally injured at the same temperature. Variation in extent of injury probably depends partly on variations in individual constitution. It does, however, also depend on the vigour of the tree and the general conditions for growth that it enjoys. Thus in the plantation referred to above many trees are growing well and will probably attain a moderately good size and produce sufficiently good timber: many others, however, have been so injured that they are dead or beyond recovery. This die-back has not been caused by suppression but by the cutting back of the tree year after year. The ability of a tree to recover from frost injury depends not a little on its power to recover from the defoliation that such injury causes. Inability to do this, and thus to maintain the vigour of the tree, is one of the chief causes of extreme susceptibility to larch canker, and in a subsequent paper it will be shown that this is one of the chief causes of the susceptibility of the European larch in particular to this disease.

SUMMARY.

1. In this paper an attempt has been made to show that frost is a very definite and often serious cause of canker in the European larch.

2. The larch canker has hitherto been held to develop in the winter: it is shown here that frost may kill the cambium, and so cause canker development, both in the spring and autumn.

3. The period during which the cambium is susceptible to frost extends from about the middle of March to the beginning of October. This includes periods during which severe late and early frosts commonly occur.

4. An examination of the temperature records at Oxford show that during the thirty-eight years from 1892–1929, spring frosts capable of injuring the larch occurred after the middle of March in over half the number of years.

5. Four cankers are examined and it is demonstrated that frost is the cause of their development. The frost ring is used as the primary diagnostic feature in this case.

6. In all these instances the larch canker fungus (*Dasyscypha calycina* (Schüm.) Fuck.), was present in the dead tissues but apparently was in no way acting as a parasite.

7. It is shown that the occurrence of canker is related to the manner of development of the cambium. In the spring the cambium first becomes active over strictly local areas, as e.g. around a dwarf shoot, or at the base of a twig, and it is in such areas that canker formation is most liable to occur.

8. Further, after canker development has begun the cambium becomes active in the region of the canker earlier than elsewhere and apparently also goes into the winter resting condition later. It is, therefore, more liable to frost injury here than in other parts of the tree.

9. It is pointed out finally that susceptibility to frost injury is not the same for all individuals of any one species and also that it is much affected by the locality in which the tree is growing. The importance of frost as a defoliating agent and of the ability of the tree to recover from such defoliation is pointed out and the relation of these to susceptibility to canker will be dealt with in a subsequent paper.

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EXPLANATION OF PLATES

PLATE III

FIGS. 1 and 2. The cambium in small normal larch stems. Fig. 1 on 18 October 1927; Fig. 2 on 25 April 1928.

FIG. 3. A frost canker on a small larch stem. The cambium has been killed in 1925, 1926, and 1927. In 1927 an eccentric frost ring is visible. Below the frost ring and at the beginning of the same annual ring can be seen another zone of abnormal tissue. Explanation in text.

FIG. 4. The two zones of abnormal tissue not far from the edge of the canker in Fig. 3.

FIG. 5. The cambium in the dead tissue in Fig. 3 lies 3 to 5 tracheids (unlignified) out from the last year's wood. The rents are typical of frost-killed phloem.

FIG. 6. A canker shown in cross section one inch above the centre. The zones of abnormal frost tissue can be seen to some extent. The dark band is due to the section being uneven in thickness.

FIG. 7. Frost rings 5¾ inches above the upper edge of the canker shown in Fig. 6. See text.

PLATE IV

FIG. 8. Frost rings 2 inches above the upper edge of the same canker (Fig. 6). In the outer ring (1929) the cambium has been partly killed and the abnormal tissue lies at the very beginning of the ring.

FIG. 9. A frost canker of very regular formation—about two-thirds full size.

FIG. 10. An enlargement of the centre section in Fig. 9.

FIG. 11. A frost canker showing very little abnormal tissue. The annual rings seen date from 1920–6 inclusive.

FIG. 12. The cambium as killed in 1924. No new tracheids yet expanded.

FIGS. 13 and 14. Abnormal wood at the beginning of the annual ring of 1924. See text.

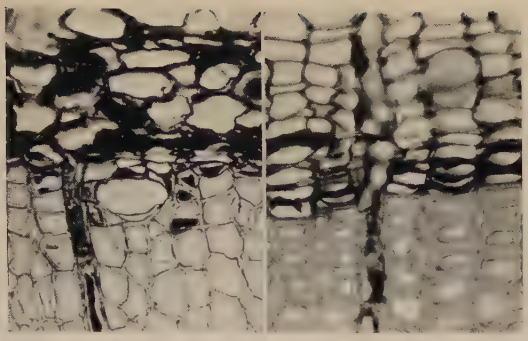


Fig. 1

Fig. 2

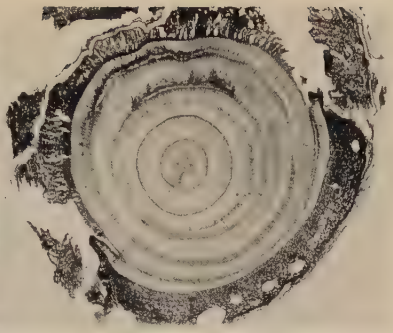


Fig. 3

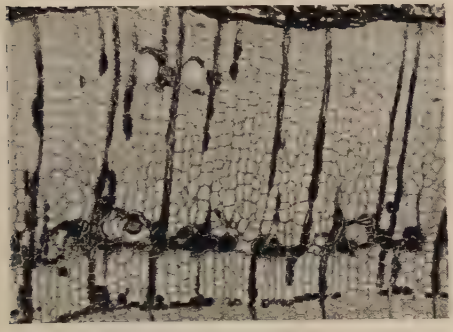


Fig. 4

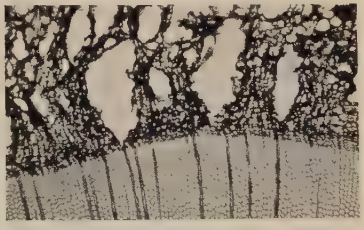


Fig. 5

Fig. 6

Fig. 7

PLATE III

FIG. 8

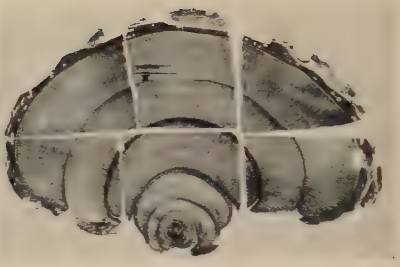


FIG. 9

FIG. 10

FIG. 11

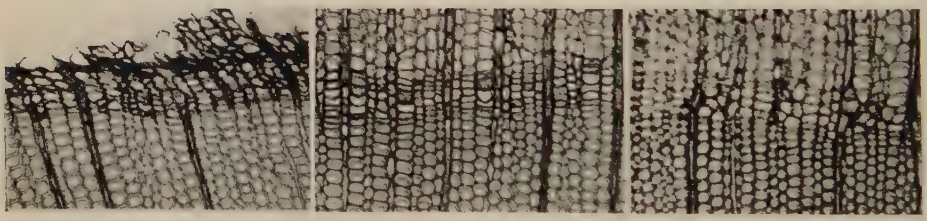


FIG. 12 FIG. 13 FIG. 14

PLATE IV

THE DRY WEIGHT OF WOOD

BY R. A. G. KNIGHT

Section of Seasoning, Forest Products Research Laboratory

INTRODUCTION.

BOTH in scientific investigations and in the commercial uses of timber, a knowledge of the moisture content is frequently required. The generally accepted definition of moisture content percentage is:

$$\frac{\text{Wet weight of sample} - \text{Dry weight of sample}}{\text{Dry weight of sample}} \times 100.$$

It is therefore of importance that the dry weight of a sample should be obtained with the requisite degree of accuracy, as well as its wet weight.

OBJECTS OF THE EXPERIMENT.

Various routine procedures have been devised to determine the dry weight of samples of wood, and generally speaking there is little difference in the various methods. Frequently, however, departures from these standard practices are made either intentionally or by accident, and this experiment was conducted to ascertain what variations would occur in the dry weights of timber samples when treated by methods differing slightly from those generally specified. The customary manner of obtaining dry weights is to place the sample in an oven maintained at from 100° to 104° C. until successive weighings show no appreciable differences, the weight of the piece being then taken as the dry weight.

It is convenient to divide the experiment into several sections, in each of which some definite object was in view. Although each part is treated as a separate unit, the results of each will be found to have some bearing on the others.

The sections are as follows:

1. The variation in dry weight at constant temperature.
2. Variations in dry weight solely attributable to temperature.
3. A comparison between dry weights obtained in dry air and atmospheric air at various temperatures.
4. The effect on the dry weight of different treatments of the sample when withdrawn from the oven.
5. A comparison of dry weights obtained thermally and chemically.

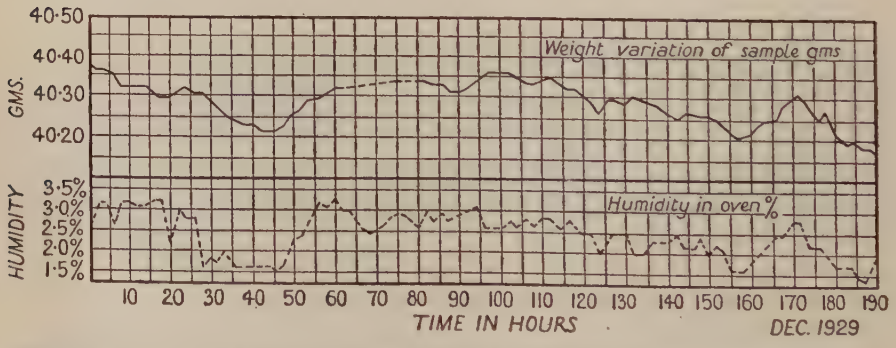
EXPERIMENTAL WORK.

The Variations in Dry Weight at Constant Temperature. A factor affecting the moisture content of wood below fibre-saturation point is the relative

humidity of the surrounding air. Generally speaking, a timber drying-oven is ventilated by atmospheric air, which is more or less moist. This air is heated to about 100° C., but as it contains its original water, the hot air is still humidified to some extent. Under normal conditions the relative humidity of the heated air is only from 1 per cent. to 3 per cent. and it fluctuates between these limits and follows changes in the condition of the atmospheric air. This small amount of humidity is sufficient to affect the weight of a wood sample, which in this case, is being tested for dryness.

The magnitude of the weight variation, over a period of eight days, was determined by means of an Oden-Keen recording balance. A sample of Scots pine was suspended from the balance and allowed to hang in a ventilated oven maintained at a constant temperature of 80° C. A continuous record of the temperature and humidity of the atmospheric air was obtained by means of a hydrograph, this being checked at regular intervals by an Assmann psychrometer. The former was scarcely accurate enough, but the latter was quite suitable for the purpose. Oven humidities corresponding to the observed hygrometric states were estimated from a standard humidity chart. The curve indicating how the dry weight varied with oven humidity is shown below. The fluctuations above and below the mean value of the sample's weight were approximately 0·2 per cent., an amount usually discernible on the average balance commonly used for moisture determination work.

Previous to this experiment, a test similar in aim had been made with Corsican pine over a period of a fortnight by taking occasional weighings of three pairs of samples of different size. The weighing-methods were not above criticism, but a subsequent test showed that little error was introduced by their use. Similar results were obtained, the degree of fluctuation being roughly the same, and independent of the size of the sample over the range of sizes used. By artificially inducing a high humidity in the atmosphere of the room towards the end of the early test, it was shown that prolonged heating did not appreciably affect the ability of the timber to absorb (and later to lose) moisture as the hygrometric environment changes.



Weight variations with humidity changes of Scots pine at 80° C. Recorded by the Oden-Keen Automatic Balance.

Variations in dry weight solely attributable to temperature. In the attempt to discover what effect temperature alone had on the dry weight of timber specimens, early experiments gave conflicting results owing to the number of variables involved, such as the humidity of the air, the temperature of the oven, and the air flow, if the oven is of the type which is designed to have a small amount of ventilation. An oven with thermostatic control was fitted to eliminate these variables as far as possible. By means of a pump and calcium chloride towers, dried air was blown into a glass tube situated in the oven and large enough to contain the required number of test pieces. Air from the tube was exhausted to the atmosphere, and all joints in the circuit were made tight. A thermometer was fitted in the sample tube, and used as a guide in adjusting the oven.

The species used in the experiment were oak and Scots pine. Four samples of each were employed, the size of pieces being $2 \times 1\frac{1}{4} \times \frac{3}{8}$ inches. The set of four samples was placed in the tube, which was maintained at certain constant temperatures over long periods during which a steady current of dry air was passing.

The samples were weighed periodically, the method being standardized as follows. Weighing-bottles, kept over calcium chloride when not in use, were weighed to within 0·0002 of a gramme. The hot samples were introduced as rapidly as possible, and there cooled for ten minutes. Bottles and samples were then weighed as before, and by difference, the sample weights obtained. The four samples of each species were approximately of the same size, and for simplicity, the four weights were averaged and expressed to the nearest milligramme. The temperature was raised and the process repeated after sufficient weighings at any stage had been obtained. The average weights at each temperature and the period during which the samples were heated are given in tabular form for the two species (Tables 1 and 2, on page 61).

Before discussing these figures, it may be well to describe an earlier experiment made with the same object in view. Samples of ten species were simply placed in an ordinary oven, and were thus subject to weight variation owing to changes in atmospheric humidity. On withdrawal from the oven, the pieces were cooled together in a calcium chloride-charged desiccator, and not in separate bottles as in the later tests. Further, the oven employed was not capable of so close a temperature regulation as that used for the second experiment. Probably by a combination of the variables mentioned before, the samples behaved in an interesting manner. At a certain temperature, the weights of the test pieces would remain constant over a long period. Such a temperature was for convenience described as giving conditions of 'complete stability'. With a temperature a few degrees higher, the samples lost weight in an irregular manner but progressively over a long period. In such a case, conditions were described as being 'doubtfully stable'. Lastly, the samples at a given temperature would lose weight continuously, when the term 'definite distillation' was applied. It sometimes occurred that a period of 'doubtful stability' was followed by one

of 'complete stability' at a higher temperature. It was thought that the explanation might be that at a certain temperature, volatile matter in the wood was evaporating slowly below its boiling-point, and on raising the temperature, the particular constituent would reach its boiling-point and pass off relatively quickly. In the second series of tests, therefore, particular attention was paid to the results, with the hope of settling definitely the validity or otherwise of the foregoing suppositions.

With the oak the weights were quite steady at a temperature of 80° C. and at 90° C. constancy was maintained until after 125 hours, when the samples commenced to fall in weight slowly but steadily. Similar results were obtained at 95° C., but from 100° to 110° C., the pieces lost weight in a regular manner.

With Scots pine, a slight loss occurred at 90° and 95° C. but at 100° C., the loss in weight was less over a similar period than at temperatures of 90° or 95° C. At 105° and 110° C., slight losses took place progressively.

Whilst from the foregoing there is some slight evidence in favour of the early beliefs—particularly in the behaviour of oak at 90° C. between 77 and 149 hours, and in that of Scots pine during the late observations at 90° C., and the early weighings at 95° C.—it is insufficient to be accepted as a confirmation, for it has already been stated that there was enough to account for the peculiar results of the earlier work in the mutual effects of slight losses in weight and the variations in drying conditions.

A comparison of the quantitative effects of the various temperatures on the weights of the samples will be facilitated if a standard of temperature and drying-time is adopted temporarily. For the former, 100° C. is convenient, as such a temperature is commonly used in moisture-content work. As to time, a period of 43 hours figures in the observations on both the oak and Scots pine, hence the weights under these conditions can best be used. These so-called 'standard conditions' are merely for use in analysing the tables and no attempt is being made at this point to define suitable conditions for general moisture determination work.

Table 3 gives the differences in weight at the various temperatures expressed as a percentage of the standard weights, and is appended on page 61. For oak, the weight difference for limits of from 80° to 110° C. is roughly $\pm\frac{1}{2}$ per cent; for a range of 5° C. on either side of 100° C. the difference is approximately $\pm 0{\cdot}2$ per cent, and slightly smaller differences were obtained with Scots pine.

Referring again to Tables 1 and 2 for oak and Scots pine, it is obvious that such distillation as occurs is slow, and as moisture determination samples are seldom allowed to remain in the oven for lengthy periods, it may be inferred that within the range considered, distillation at a given temperature will not seriously affect the dry weight of the sample. For some timbers of an oily or a very resinous nature, however, it is stated that distillation commences at a very low temperature, and occurs to an extent which prohibits the use of the oven-drying method as a reasonably accurate means of moisture determination.

Table 1

Summary of Results with Oak.

Weights in grammes; times in hours.

80° C.		90° C.		95° C.		100° C.		105° C.		110° C.	
Time.	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*
38	10·628	5	10·623	33	10·601	18	10·585	27	10·562	24	10·537
46	10·627	23	10·623	45	10·602	24	10·583	50	10·558	48	10·533
64	10·627	30	10·620	53	10·602	43	10·582	75	10·555	72	10·533
73	10·626	47	10·621	70	10·601	53	10·580	118	10·552	91	10·532
93	10·625	59	10·621	76	10·602	68	10·579	145	10·552	116	10·529
111	10·626	71	10·620	98	10·601	90	10·577	171	10·549	143	10·526
..	..	77	10·619	118	10·600	114	10·575	213	10·549	168	10·523
..	..	96	10·620	125	10·597	139	10·573	241	10·548	..	..
..	..	125	10·622	142	10·595	161	10·571	286	10·544	..	..
..	..	149	10·619	176	10·594	193	10·570	338	10·540	..	..
..	..	167	10·619	220	10·593	212	10·569	..	..	..	..
..	..	197	10·615	244	10·593	236	10·565	..	..	..	..
..	..	222	10·611	268	10·593	265	10·564	..	..	..	..
..	..	245	10·612	293	10·595	285	10·562	..	..	..	..
..	..	265	10·607	311	10·592	..	..	..	..	..	..
..	..	312	10·607	340	10·593	..	..	..	..	..	..
..	..	..	..	359	10·590	..	..	..	..	..	..

Table 2

Summary of Results with Scots pine.

Weights in grammes; times in hours.

90° C.		95° C.		100° C.		105° C.		110° C.	
Time.	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*	*Time.*	*Weight.*
26	6·760	28	6·755	20	6·744	44	6·738	41	6·732
49	6·759	74	6·755	43	6·745	69	6·737	66	6·730
74	6·760	94	6·753	91	6·745	119	6·736	92	6·729
102	6·759	149	6·751	163	6·743	170	6·734	117	6·726
144	6·759	172	6·751	212	6·741	..	..	..	..
172	6·757	196	6·749	240	6·741	..	..	..	..
217	6·757	240	6·749	..	..	..	..	..	..
266	6·755	338	6·747	..	..	..	..	..	..

Table 3

Percentage Variation in Dry Weight of Timber at Different Temperatures.

Temp. in °C.	*Weight in grammes.*		*Hours in oven.*		*Difference from standard weight.*		*Percentage difference based on standard weight.*	
	Oak.	*Scots pine.*	*Oak.*	*Scots pine.*	*Oak.*	*Scots pine.*	*Oak.*	*Scots pine.*
80	10·627	..	46	..	+0·045	..	0·43	..
90	10·621	6·759	47	49	+0·039	+0·014	0·37	0·21
95	10·602	6·755	45	28	+0·020	+0·010	0·19	0·15
100	10·582	6·745	43	43	..	..	..	..
105	10·558	6·738	50	44	−0·024	−0·007	0·19	0·10
110	10·533	6·732	48	41	−0·049	−0·013	0·46	0·19

A comparison between weights of wood obtained in atmospheric and dry air at different temperatures. The ideal way of obtaining the dry weight of a wood sample is to maintain it in perfectly dry air at a given temperature. Such a method, however, is impracticable for general use, because of the difficulty of supplying dried air to an oven.

This third test was made to compare the weights obtained in atmospheric and dried air of samples of wood when subjected to pre-arranged temperatures. The apparatus used was that described in the previous section, the various drying towers being removed or short-circuited when atmospheric air was required in the tube. The weighing-methods employed were also identical.

Two species were tested simultaneously, namely teak and larch, two samples of each being used, and the sizes were $2 \times 1\frac{1}{4} \times \frac{3}{8}$ inches. The samples were weighed after approximately 24 and 48 hours under each condition, and as there were only slight differences between the two weights, an average was obtained and recorded in Table 4, below. As would be expected, the samples both in atmospheric and dry air decreased in weight as the temperature rose, but the weight loss was greater for the former pieces since the effects of a lowered humidity were coupled with the thermal loss. As the temperature increased, the difference between the weights of the samples under the two conditions became less, the percentage difference at 90° C. being roughly halved at 110° C. The remarkable constancy of teak must be pointed out. This wood responds very little either to temperature changes or to the additional drying powers of the dehydrated air.

Taking the larch figures as being the more normal and again adopting an arbitrary standard temperature of 100° C., the dry weight in atmospheric air is roughly 0·4 to 0·5 per cent. above that in dry air.

TABLE 4

Comparison of Dry Weight obtained in Atmospheric and Dried Air at Certain Temperatures.

	Teak.			Larch.		
Temperature ° C.	*Weight in atmospheric air.*	*Weight in dry air.*	*Difference.*	*Weight in atmospheric air.*	*Weight in dry air.*	*Difference.*
90	9·435	9·398	0·037	8·217	8·162	0·055
95	9·428	9·400	0·028	8·199	8·156	0·043
100	9·425	9·400	0·025	8·189	8·154	0·035
105	9·420	9·400	0·020	8·175	8·147	0·028
110	9·416	9·398	0·018	8·167	8·142	0·025

The effect on dry weight of different treatments after withdrawal from the oven. The laboratory practice of weighing the sample in a bottle is too cumbersome for general use, and in routine work it is customary to weight the bare sample immediately after removal from the oven and whilst it is still hot. To test for the error introduced by this and other methods as compared with the use of a

weighing-bottle, two sets of four oak samples, $2 \times 1\frac{1}{4} \times \frac{3}{8}$ inches in size, were conditioned in separate places in the laboratory. One set was of transverse section samples and the other of tangentially sawn pieces. The validity of the test depended on the uniformity of moisture content in each set of samples, and to this end, the pieces were matched sections and were weighed during conditioning until each in a set showed the same degree of fluctuation.

Four samples were placed in the tube oven of the previous test and dry air blown through, dry air being used so as to make the pieces as sensitive as possible on withdrawal from the oven. After suitable drying periods, a sample was weighed hot from the oven, a second placed in a bottle and cooled before weighing, a third cooled in air for eight minutes, and a fourth cooled in a desiccator over phosphorus pentoxide and weighed in a bottle. From the observed wet and dry weight, the moisture contents were estimated, the mean of several observations being recorded in Table 5, below.

The results are given to a greater degree of accuracy than is justifiable, but are probably correct to the first decimal place. It will be seen, therefore, that there is little to choose between a quick weighing of a sample hot from the oven, the normal weighing-bottle method, and the cooling-over a drying agent. The test of allowing the piece to stand in air was introduced to give some idea of the rate of absorption of a dried sample, and it illustrates that a hot test-piece will not pick up any great amount of water during the short time required for its weight to be found.

TABLE 5

Moisture Contents.

Samples.	*Manner of weighing samples.*			
	Hot from oven.	*After cooling in bottle.*	*Cooled in air for 8 minutes.*	*Cooled over phosphorus pentoxide and weighed in bottle.*
	Per cent.	Per cent.	Per cent.	Per cent.
Transverse section. . .	9·01	9·12	8·82	9·02
Tangential section . .	8·13	8·18	7·97	8·10

A comparison of dry weights obtained by chemical and oven-drying methods. In many physical and chemical operations, the drying of materials is done in the presence of suitable agents in closed vessels at ordinary temperatures. Calcium chloride and phosphorus pentoxide are two commonly used driers, both being capable of de-hydrating air to a very low percentage of humidity. It was thought that it would be interesting to compare the dry weights of wood samples obtained by using these two chemicals and by the more usual method of oven drying. Sets of five samples of six different species were weighed initially, then placed over calcium chloride until in equilibrium and their weights again obtained. The samples were transferred to phosphorus pentoxide desiccators

and the process repeated, and finally they were dried in an oven through which a small quantity of atmospheric air was passing, the temperature being about 100° C. On removal from the oven, the samples were cooled over calcium chloride, but it has been shown that this would scarcely affect the result. On an average, the moisture content as obtained from dry weights over phosphorus pentoxide was 1 per cent. higher than from those over calcium chloride. This would be expected, since the relative humidity in the presence of phosphorus pentoxide is stated to be very small. With the exception of one softwood, all the species attained a lower dry weight in the oven than over phosphorus pentoxide, which was unexpected, since some humidification has been shown to exist in an oven. The result most probably indicates that the loss in weight of wood whilst oven drying is not only water, but that some chemical distillation of other constituents also occurs. Such chemical methods as were used in the test are quite impracticable for any but special tests, owing to the extreme slowness of the drying process.

SUMMARY OF RESULTS.

1. The normal variations in atmospheric humidity induce fluctuations in dry weight of a sample to the extent of $\pm 0{\cdot}2$ per cent. of the mean value, when the oven has provision for ventilation.

2. It does not seem that a wood sample when heated at temperatures of 80° C. or over, will attain an absolutely steady weight, even when the treatment is continued for the lengthy periods employed in the experiment. The loss is slight, but quite appreciable by accurate methods of weighing.

3. For a temperature range of 5° C. on either side of 100° C., the dry weight of wood will be heavier and lighter respectively by about 0·2 per cent. of the mean weight at 100° C., this being solely a thermal effect and apart from variations due to hygrometric causes.

4. At 100° C. the weight of a sample in atmospheric air is roughly 0·5 per cent. greater than when heated in dry air.

5. The weight of samples dried in an oven at 100° C. in atmospheric air is slightly less than when kept over phosphorus pentoxide at room temperatures.

6. A negligible error is introduced by weighing the test piece hot from the oven, or cooling it over calcium chloride as compared with the weighing-bottle method.

CONCLUSIONS.

The determination of the moisture content of a piece of wood is more often a routine operation than a purely scientific test, and refined methods can seldom be employed except in special cases.

It is better, therefore, to consider the results of the foregoing experiments from the more generous outlook of every-day work than from the scientific aspect.

The use of dried air in an oven can be dismissed from the discussion as being impracticable on any but a laboratory scale, and if used then, the results would not be comparable with those of general moisture determination practice.

Probably 100° C. is the most convenient temperature to employ, and in normally ventilated ovens the effects of a fluctuation of $\pm 5°$ C. may be nullified or doubled by hygrometric variations.

By reasonably careful work, the maximum error should not exceed about half per cent in the dry weight of the sample, and the effect of this on the resultant moisture-content estimation should not exceed $\pm \frac{3}{4}$ per cent when dealing with stock of average air-seasoned dryness.

Confidence can be placed in the generally accepted instructions for determining moisture content, namely, 'obtain the wet weight of the sample, dry in an oven at about 100° C. until no further loss in weight occurs, then apply the usual formula:

$$\text{Moisture content percentage} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100 \text{ per cent.'}$$

THE FORESTS OF SWEDEN

The Main Results of the Royal Swedish National Forest Survey and a Short description of the Method employed

BY ERIK THORELL

Assistant Secretary, National Forest Survey of Sweden

IN recent years one of the most valuable forest territories of northern Europe has been the subject of a significant investigation. We refer to the general inventory of the forests of Sweden which includes the area and the site-quality of the forest land, the cubic volume, annual increment, and composition of the timber supply. This interesting work has been completed recently for the whole country and through it the Swedes are fortunate enough to have an extensive knowledge of one of their most important natural resources. As the forest conditions and the forestry of Sweden, during the last few years, have become important even far outside the boundaries of the country, a short description of the general forest survey is given herewith. In this connexion it may be added that Norway and Finland have recently completed a general forest survey and that a survey of certain sections of the forests of U.S.A. in accordance (approximately) with the method used in Sweden has been started.

Time and again rough estimates of the timber supply of Sweden have been made. The results have, however, varied considerably owing to incomplete basic data and to the crudeness of the methods used. In 1907, however, a Swedish forester proposed that the old Swedish linear or strip survey method should be employed in the investigation of large forest areas. The mathematical reliability of the method was looked into and it was found that it might be expected to yield satisfactory results at a reasonable cost. Subsequently, the method was further developed and tested by a trial forest survey of the entire province of Värmland, in central Sweden, in 1911. This inventory was found to satisfy fully all demands as to accuracy and detail of results. As the line-survey method permits the arrangement of the basic data by groups it was possible to test the reliability of the method with the aid of the Calculus of Probability—the first time this has been employed in connexion with a linear forest survey. The Commission responsible for carrying out the trial survey in 1914 outlined a scheme for taking stock of the forests throughout the entire country. The immediate realization of this plan was, however, prevented by the War and the critical years that followed, so that it was not until 1923–9 that the Swedish national forest inventory could be made. In the course of this survey the forests have been investigated in conformity with the method used in 1911, which, however, was further improved in 1923 by specially appointed experts. At first the inventory was carried on by the Forest Service, but in

1924 the management of this extensive work was taken over by a Royal Forest Survey Committee, which worked directly under the Department of Agriculture. The president of this committee is Professor H. Hesselman, Chief of the Forest Experiment Station in Stockholm, and the managing member and secretary is Dr. J. Östlind, Assistant Chief of the Royal Board of Pension. The other members are Professor T. Jonson, Dean of the Royal Forestry Institute in Stockholm, and Mr. W. Ekman, President and General Manager of one of Sweden's oldest and largest forest and lumber companies.

A nation-wide forest survey was suggested by some far-sighted men, prominent in the science of forestry, in the forestry and lumber industries, and in the forest societies. They were of the opinion that more than the annual increment of the forests was being cut. (It may be mentioned that the depletion of the forests by fires and insects can be left out of consideration in Sweden.) The main object of the survey was to ascertain the annual increment of the forests and with the aid of reliable statistics of timber consumption (as yet only crude figures are available, but the work in getting up-to-date consumption statistics is already progressing) to make up a plan regulating the annual cut so that it would not exceed the annual increment. Moreover, information might be gathered as to what measures would increase the annual yield from the forests. It may be stated that the forests are the most important source of income in Sweden. Out of the forests alone come raw products for articles of export, the value of which amounts to half the total value of exports.

As the intention was to determine the timber supply of the whole country, both state and privately owned forests were investigated. According to the latest obtainable figures the forests of Sweden are distributed among different owners as follows:

States forests proper	20·1 per cent
Other public forests	3·8 „ „
Forests of limited companies	27·0 „ „
„ „ large landlords	3·4 „ „
„ „ smaller landlords	45·7 „ „
Total	100·0 per cent

The money necessary for the National Forest Survey was set aside by the National Parliament, and its members have always treated this important question with great interest regardless of their political views. Also everywhere in the country people were very interested in this work and all classes eagerly awaited the results of the survey of the districts investigated during the year.

Sweden's total area is divided as follows:

Land area	158,525 square miles
Lakes and rivers	14,625 „ „
Total area	173,150 square miles

Naturally every acre of productive forest land could not be surveyed, nor each tree counted, but a number of sample plots were laid out to cover the various provinces. As the topographical conditions of Sweden are very variable,

these sample plots were in the form of long strips, 33 feet wide. These strips or lines were parallel and ran from boundary to boundary of the Kingdom or from coast to coast. The distance between the strips, which was determined on the basis of the results obtained as to reliability in the trial survey carried out in 1911, varied in north Sweden between 6·2 and 12·4 miles and from 0·6 to 3·1 miles, in central and southern Sweden, where they ran west-east, while in northern Sweden they were oriented from south-west to north-east. In this way the survey lines were, for the most part, drawn at right angles to the main topographical direction, and therefore different land classes were included in correct proportion to their area. The survey lines, which were drawn up on good topographical maps, were followed in the field by means of a compass.

Along these lines the different surveying parties—10 to 12 men in each and with a trained forester as chief—have been working. The total length that they have covered, corresponds to a distance more than 1¼ times around the equator. This figure, however, does not include the distance between the clusters of islands, where motor boats were used, or the strip lengths over prairie land, where motor cars and also aeroplanes were used for reconnoitring. In the forested districts, of course, the surveying parties travelled their long way on foot and had carriers to transport tents, victuals, and kitchen utensils. Here and especially in the desolate parts of northern Sweden they led the life of pioneers, while in the more settled tracts they lived with the country people. Every day the parties worked ahead 4 to 5 miles and every night they pitched their camps at a new place or took up their quarters at another farmstead. Each summer they were marching day after day along their survey lines.

When the party worked their way through the forests the compass man went first, and with the help of his compass showed the party the way straight over fell and dale, through swamp and morass, over lakes and rivers always straight on. He drew a drag-rope, 330 feet long, and within a distance of 16½ feet on both sides of the rope all trees, with the exception of those of the smallest dimensions, were counted and measured by two men with calipers, the measurements being recorded on a special form by a forest ranger who was also the foreman of the party. A certain previously fixed number of the recorded trees of each species and diameter class were selected at random as sample trees. These were thoroughly investigated by a sample-tree-taker and his assistant. Records were made of height, taper, cubic volume, diameter and height increment as well as the age and defects for each tree on a separate card. The data of these cards were later used for calculating the cubic volume and increment of these and all recorded trees.

Along the drag-rope the length over areas of arable or productive forest land, pasture, bog, fjeld, rock outcrops, lakes and rivers, gardens or roads, &c., was measured by two chain-men, the leader of the party recording the measurements on a special form. The productive forest land was further subdivided and classified according to productivity and forest types, and a note was made from the standpoint of forestry management. The distance over lakes and rivers was determined by indirect measuring or by taking the length from the map.

When crossing a lake or a river the crew often had to fell trees and build a raft on which to transport themselves and their baggage.

One to three carriers took care of and transported the baggage. On paths and roads, sometimes in boats, the carriers went along to the place intended for passing the night, while the survey party worked its way along the strip. All the time the supervisor of the field work controlled the work of the different surveying parties. As a thief in the night he would swoop down upon the unsuspicious party. The procedure of control was as follows: the last investigated 2 km. distance was resurveyed and a comparison between the two results showed whether the party was surveying with sufficient precision or not. Every summer three or four provinces were investigated by 8 to 10 parties, covering in each surveying season an average distance of more than 4,600 miles.

Once a week the leader of the party sent the material collected to the office of the National Forest Survey Committee at Stockholm, where it was carefully checked. In the autumn when the field work was completed, the compilation of the statistics was gone on with. There were thousands and thousands of forms and a vast amount of data to be dealt with. Accuracy was also the first and the last word. About 20 persons, including 10 ladies, were continually employed with the compilation, aided by the most up-to-date office machines.

As already mentioned, the surveying parties during the summers of 1923–9 have cruised a distance longer than round the equator, a belt of 32,300 miles in length. At the same time over 180,000 sample trees have been investigated. In the autumn of 1929 the field work was completed with the re-surveying of the province of Värmland, where the trial survey had been made nearly twenty years ago. Thus all the provinces of Sweden, with a total land area of 101·5 million acres, were investigated by the same standard method.

The results of the survey of the entire country were available in a fourth and final report to the King in December 1929, only three months after the field work was completed. These four reports give a very detailed account of all that is interesting and important regarding the forestry conditions in the twenty-four provinces of Sweden. In the tables given here, however, only the most important results are drawn together for the three large sections, northern, central, and southern Sweden (Norrland, Svealand, and Götaland), into which the country of old, both administratively and geographically, was divided.

In Sweden the total productive forest land comprises 57·3 million acres, or 1 million hectares less than the total area of Great Britain and the north of Ireland, corresponding to 56·5 per cent of the total land area. In the productive forest area, pasture land is also included, but not broadleaved forests above the coniferous timber-line or other forests of poor growth, i.e. forest land with a yearly timber-producing capacity of less than 14·3 cubic feet per acre. Arable land, gardens, and building areas occupy 12·6 per cent of Sweden's land area, bogs 14·3 per cent, land above the coniferous timber-line (fjeld) 13·9 per cent, rock outcrops, roads, and other waste land 2·7 per cent. The total productive forest land is made up of 96 per cent forest land proper and 4 per cent pasture forest land. Of the total productive forest land 8 per cent

is bare forest land and 8 per cent consists of forest land in need of drainage in order to reach maximum producing capacity.

The greater part of Sweden's productive forest land is covered with coniferous forests of pine and spruce. Only in some of the southern provinces are the forests broadleaved, consisting of birch, beech, oak, and ash, &c.

The average yearly timber-producing capacity of productive forest land with up-to-date management varies from 38·6 cubic feet per acre in northern Sweden to 57·1 cubic feet in southern Sweden. The average for the whole country is 45·7 cubic feet per acre.

The producing capacity, however, is not utilized to more than two-thirds of the maximum. According to Swedish ideas, the area of bare productive forest land is rather extensive, comprising nearly one-quarter of Scotland's total area or 4·44 million acres, but intensive work is going on in order to afforest these areas. The Government has already appropriated substantial sums of money for this undertaking, but the appropriations will be increased. To begin with a 15-year plan for reforesting private forest land which prior to 1905 had been devastated, is being followed. The cost is estimated at £3,500,000, the Government contributing one-half, a respectable sum for a country with a population of only six million. From 1905 onwards, mismanagement and devastation of the forests was prevented by a general forest law. Besides these sums considerable contributions have been voted for other forestry needs. The Swedish Government thus shows that it fully realizes the important part forestry plays in Sweden. At present the belief is widely spread that the world's supply of merchantable conifers is rapidly being exhausted. It surely would be fortunate for universal management, if, in conformity to an old desire, up-to-date forestry data were obtainable from all countries as is now available in regard to forest conditions in Fenno-Scandia.

In Sweden there are 10,348 million trees of at least 4 inches diameter over bark at breast height. The number is 172 per acre of productive forest land, of which 36 are at least 8 inches in diameter, i.e. timber trees. The total volume timber in the forests of Sweden amounts to 50,062 million cubic feet, under bark, which corresponds to an average cubic volume per acre for productive forest land of 844 cubic feet, exclusive of bark. The timber supply consists of 40 per cent pine, 42 per cent spruce, and 18 per cent broadleaf trees. If the bark is included, the figures would be raised by 20 per cent. The annual wood increment amounts to 1,683 million cubic feet, exclusive of bark. The annual growth consists of 38 per cent pine, 42 per cent spruce, and 20 per cent broadleaved trees. The average annual increment per acre of productive forest land is 28 cubic feet. The best increment is obtained in some of the provinces of central Sweden, where the growth amounts to 49 cubic feet per acre. The average volume increment per cent of all coniferous trees is 3·25 per cent, and 3·90 per cent for broadleaved trees 2 inches diameter and upwards. Broadleaved trees less than 2 inches over bark at breast height were not included in the survey.

If the bark-volume is included, the total timber supply will amount to about

60,000 million cubic feet and the annual increment to about 2,000 million cubic feet. This is as regards the timber supply, 14,600 million cubic feet, and as regards annual increment during the immediately preceding 10 years, 850 million cubic feet more than even the boldest earlier estimates. The National Forest Survey, however, also showed that Sweden's forest land is able to produce still more timber, but to secure this forestry management must be still more up-to-date. Steady progress is being made in improving forestry technique. The area that was the subject of the trial survey in 1911, the province of Värmland, showed upon being re-surveyed in 1929, considerable improvement in the conditions of its forests, with a substantial increase in both cubic volume and annual growth.

In the survey, the actual investigated or cruised area was 0·14 per cent of Sweden's total land area. The calculations made to ascertain the reliability of the results have shown that the sample method adopted for the purposes of the National Forest Survey reached a high standard of accuracy. It may safely be claimed that the results for the entire country, in regard both to area of productive forest land and to cubic volume and increment, cannot show at the most more than 2 per cent divergence from the results one would have obtained had the entire country been covered with survey strips 33 feet (10 metres) wide and by the same methods of procedure.

The results quoted here are only a few of all those obtained in the Swedish National Forest Survey. Figures are given not only for the different provinces but also for various areas at different elevations and for watersheds. The last-mentioned information is of a special importance for the big cellulose and lumber industries situated as a rule at the mouth of the rivers to which the timber is transported almost exclusively by river-floating. By means of the survey these industries have obtained a valuable and exact statement of the natural resources of their purchasing areas.

The National Swedish Forest Survey intend to publish a comprehensive and detailed report which will appear in 1931–2. In the near future the plan is to compile special statistics of timber consumption for the whole country. Then the Swedes will be perfectly certain regarding both the debit and credit sides of the balance-sheet of their forests.

The total expenses for the National Forest Survey are estimated to amount to about £77,000 (1,400,000 Sw. Crowns), of which one-third was for the compilation. The total cost corresponds to 0·18*d.* per acre of land area or 0·32*d.* per acre of productive forest land, a low cost for such a far-reaching and detailed investigation.

Recently, a short preliminary report of the main results has been published, including an English edition. This may be obtained by interested persons upon application to Riksskogstaxeringsnämnden, Stockholm.

Total cubic volume exclusive of bark, its division into species and cubic feet per acre.

Section.	Diameter classes. Inches outside bark.	Timber supply (under bark volume) of all trees. In millions.	Thereof				Volume per acre of		
			Pine.	Spruce.	Birch.	Other species.	forest land proper. Cu. ft.	pastured forest land. Cu. ft.	total productive forest land. Cu. ft.
			Per cent.						
Northern Sweden	0–18	27,533	38·6	43·2	15·5	2·7	797	206	793
	4–18	23,581	40·8	43·7	13·0	2·5	687	161	683
Central Sweden	0–18	13,053	43·7	44·2	9·0	3·1	1,020	397	989
	4–18	11,474	45·8	43·8	7·7	2·7	900	346	873
Southern Sweden	0–18	9,476	42·1	33·2	14·0	10·7	903	389	832
	4–18	8,607	43·6	33·3	12·6	10·5	826	356	760
Total for Sweden	0–18	50,062	40·6	41·6	13·5	4·3	866	373	844
	4–18	43,662	42·7	41·7	11·5	4·1	759	333	740

The division of the total coniferous timber supply into age-classes.

Section.	Species.	The age of the trees in years							Thereof		
		1–20	21–40	41–60	61–80	81–100	101–120	over 120	121–140	141–160	over 160
		Per cent.									
Northern Sweden	Pine	0·1	3·0	11·0	18·2	13·9	8·5	45·3	8·3	7·4	29·6
	Spruce	0·3	3·3	9·4	15·0	15·0	12·2	44·8	9·2	7·7	27·9
Central Sweden	Pine	1·0	9·7	20·8	23·2	17·8	9·8	17·7	6·4	3·3	8·0
	Spruce	0·7	11·0	27·1	25·0	15·9	8·6	11·7	5·2	2·7	3·8
Southern Sweden	Pine	1·8	17·2	29·5	24·8	14·2	6·6	5·9	2·9	1·4	1·6
	Spruce	1·7	22·7	37·6	22·7	9·6	3·3	2·4	1·4	0·6	0·4
Total for Sweden	Pine	0·7	7·7	17·4	20·9	15·1	8·5	29·7	6·7	5·0	18·0
	Spruce	0·6	8·4	18·6	18·9	14·4	9·9	29·2	6·9	5·2	17·1

SOCIETY AND OTHER NEWS

OBITUARY

Captain William Stewart of Shambellie

Only the shortness of the period of his membership prevented Captain Stewart from becoming well known and much liked by the members of this Society, which he joined as an Ordinary Member last autumn. Had he lived to take part in its activities as he did in those of other Forestry Societies, he would soon have made many firm friends amongst us. As a resident proprietor who managed his woods on economic lines he was a most interesting man to visit and would take no end of pains to show his guests all that Shambellie could teach them. His Scots pine stand had the heaviest volume per acre in the country and he was justly proud of it. His passing on the last day of 1930 has left private forestry in Scotland with a gap that in these days will be difficult to fill.

THE ANNUAL EXCURSION

Preliminary arrangements have been made to hold the Excursion this year from 1 to 3 October, being the three days immediately after the Meetings of the British Association which take place in London from 23 to 30 September. Head-quarters will be in Buckinghamshire, where the party will assemble on the evening of 30 September.

The following is the proposed programme: *Thursday* 1 October, will be spent at Princes Risborough, where the Forest Products Research Laboratory will be visited and a General Meeting held. Next day will be devoted to the Furniture Factories and Woodworking Industries in High Wycombe. The last day will be occupied by a visit to the Earl of Hampden's estate at Hampden House, where an opportunity will be afforded of studying his beech woods, working plans, and utilization.

A circular giving further details and an estimate of the cost will be issued to members in due course. Meantime, members are asked to note the dates and keep themselves free.

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

Members are reminded that nominations for election to office at next Annual General Meeting must be in the Secretary's hands by 31 October next, and that the nominations must be in writing and signed by two Professional members. THERE IS NO special form for making nominations and no special reminder can be sent to members nearer the closing date. The initiative is with the members. Nominations are required for the following:

Office-bearers: President, Vice-President, Editor of Journal, Business Editor, Secretary, Treasurer, Auditor.

Councillors: 3 members, to hold office for years 1932 and 1933.

THE PROBLEM OF FIRE IN BRITISH FORESTS

Insurance: Since the preparation of Mr. Taylor's article in vol. iv, no. 2, modifications of some importance have been agreed to by the Scottish Insurance Companies. The normal rate of 5*s*. per cent (reduced to 4*s*. per cent if the growing timber is forty years

old or over) remains unchanged, but the additional rates for area and for proximity to public road or railway are reduced when the growing timber is over fifteen years old and still further reduced when the age is over forty years. Moreover, the principle of a maximum charge for area has been conceded—with great benefit to proprietors whose woodlands are extensive—and the warranty prohibiting the lighting of fires has been withdrawn.

INTERNATIONAL CONGRESS OF TIMBER AND SILVICULTURE

An International Colonial Exhibition will take place this summer in Paris, and on this occasion an International Congress on Timber and Silviculture will be held from the 1st to the 5th July.

It will include four groups:

Group I: Tropical and subtropical Timbers, in which Silviculture, Production, Transport, Marketing, and Utilization will be dealt with.

Group II: Silviculture and Forest Pathology, in which forest technique, economics, legislation, afforestation, fire protection, and pathology will be dealt with.

Group III: Commerce, Industry, and International Relations.

Group IV: Technical Education.

There will be excursions to the harbour of le Havre, which is an important point of ingress for foreign timbers, and to the Alps, where seven or eight days will be spent.

Particulars can be obtained from M. Colomb, Conservator of Forests, 65 Avenue de la Grande Armée, Paris (16e).

REVIEWS

Handbuch der Freien Durchforstung mit Beiträgen zum forstlichen Versuchswesen. Dr. Carl Robert Heck. E. Schweitzerbart'sche Verlagsbuchhandlung, Stuttgart, 1931. Price Mk. 30.

Review by W. H. Guillebaud.

THERE are few occupations in which experience counts for more than in forestry and also few in which there is greater danger of being unable to 'see the forest for the trees'. In forestry the latter defect tends to manifest itself in the shape of rigid regulations and prescriptions based largely on theoretical considerations, which tie the hand of the practising forester, and often are highly injurious to the forest itself. It must interest all of our profession to know that the author of 'Freie Durchforstung' is a man of 70 years of age who has spent over 30 years of his life in the forest, and for the whole of that time he has been putting his own principles into practice. Our sympathies are further engaged by the title 'Free Thinning', or as the author first named it 'Thinning with a Free Hand'. Here are no rigid rules or formulas but a set of principles based on keen observation and lengthy experience. In the early part of his service, Heck was attached to the Württemberg Forest Research Station and for some years worked on permanent sample plots. At that time, about 1890, German forestry was still almost wholly under the sway of the theory of maintaining dense canopy, and thinnings, rarely if ever, included any of the dominant stems. By 1897 Heck had established his first pair of comparative thinning plots, one of which was based on his free thinning, which permitted or even encouraged the felling of trees in the upper canopy. In the following year he published his first article under the title 'Freie Durchforstung'. There is then some justification for his claim to be a pioneer in German thinning practice and to have been one of the first to invade the sanctity of the upper-crown layers of immature stands. In Lorey's *Encyclopedia of Forestry*, Heck's system of Free Thinning is described as virtually equivalent to the E. or heavy Hoch Durchforstung grade of the latest 1903 series of thinning grades laid down by the German Forest Research Stations, the priority being obviously due to Heck. The statement that the two systems are identical is vigorously challenged by our author, but after a careful scrutiny of the comparative plot data, it would appear that the difference is perhaps rather one of emphasis and of detailed procedure than of principle.

The essence of 'Free Thinning' is the early selection of a relatively small number of perfect trees uniformly distributed over the area, these trees being tended—cherished is the more appropriate term—throughout the life of the stand. Most thinning specialists, when they set out to mark a stand for thinning, whatever the grade of thinning to be applied, tend to consider first how many of the ugly mis-shapen trees can be got out. If the grade is a crown thinning or a heavy low thinning the opportunity is eagerly seized of marking as many as possible of the large wolf trees, corkscrew stems, forked trees, and so on without leaving excessively large gaps. Heck's method is different, his preoccupation is solely with the perfect stems, which must be spaced anywhere from 13 to 20 feet apart, that is, 100 to 260 trees per acre. His definition of a perfect stem is extremely rigid, namely, a stem which is quite straight when viewed

from two directions at right angles, with a clean bole of more than 33 feet in length. As far as possible these are to be selected in the predominant or dominant class. If, as is often the case, there is no perfect stem at the required spacing, i.e. from 13 to 20 feet away from the nearest selected tree, the next best stem is chosen. These *alpha* stems (Heck carefully avoids the use of the word *élite*) are very cautiously freed, at first by the removal of one neighbour on the most crowded side and gradually given more and more freedom to develop a full symmetrical crown, but preserving subdominant or dominated trees to prevent any permanent break in the canopy. As soon as the *alpha* stems can be recognized they are pruned, removing all the dead branches together with the lowest one or two whorls of moribund branches and at every second thinning, i.e. every 10 years, pruning is repeated until the required length of clean bole is attained.

One of the obscurities in the author's description of his method is that it is not clear on what basis he classifies his *élite* stems in young stands where it is obviously impossible for the trees to have a clean bole of over 33 feet in length.

The main features of free thinning may be summed up as follows:

(1) The selection of a small number of well-distributed *alpha* trees at as early a stage as possible.
(2) The essential character of an *alpha* tree is that it should be vigorous in growth and possessed of a perfectly shaped stem. Crown form is of subordinate importance at first; this can be secured by skilful tending, including pruning if necessary.
(3) The gradual, progressive, freeing of the crowns of the selected stems but without permanently breaking the canopy. This distinguishes free thinning from any of the forms of 'Lichtung' thinning.
(4) The pruning of the *alpha* stems at an early stage. Heck considers that pruning should start when the stems have a breast-height diameter of not more than 4 inches (8 inches is the outside maximum).
(5) Complete freedom to remove at any age trees in all canopy classes, including predominants, if necessary, to favour the *alpha* trees.

Now the author admits the obvious fact that his system will produce a wide-ringed fast-grown timber of large dimensions, but he argues the point at considerable length as to whether better prices can be obtained in practice for narrow-ringed than for wide-ringed timber, and comes to the definite conclusion that this is not the case. The only exceptions which he is prepared to admit are in the case of oak, in which the timber must be close-ringed to be of best quality, and spruce when used for certain special purposes (resonance wood).

An important section of the book contains a detailed account of a number of comparative sample plots of different species in which Heck has tried out his own method alongside other systems of thinning. In general these bear out his contention that by centring attention on the best trees the number of these can be increased, and both volume and value increment raised substantially.

Apart from the particular case which Heck has endeavoured to establish with the aid of these sample plots, this section of his book contains many points of general interest, among which may be mentioned what the author terms the wandering of the trees through the door of the stem classes. All the plots have been classified by the system of stem classification devised by Kraft in 1884, but with the important modification that whereas Kraft's classes were based on position in the tree canopy and, to a subordinate extent, on the form of the crown, Heck introduces a further subdivision of Kraft's classes based on the form of the stem and length of clean bole. Some of the

sample plots have been remeasured six and seven times and some very interesting tables are given showing the fate of trees of the different stem classes. Out of 6 sample plots, mostly about 0·5 acre in area, only 24 dominant trees passed up into the predominant class, only 3 co-dominant became dominant, and 4 sub-dominant became dominant. In one plot of common ash, it is interesting to note that 4 sub-dominant trees passed up into the pre-dominant class. All of these stands were over 40 years of age at the time of establishment, and it is evident that by the time the trees have reached that age it is seldom worth while favouring a tree of lower than the dominant class, because only few are capable of responding. The fact that sub-dominant ash may be nursed to a state of pre-dominance should encourage the favouring of well-shaped but relatively small stems of this species.

It is also of interest to extract from the tables the number of 'perfect' stems in the upper canopy (Kraft's classes 1 to 3) and to compare them with the total number of dominant trees. This gives some indication as to how far the ideal of a uniform distribution of 'perfect' stems can be realized in practice. The following table shows the position in plots which have been treated by Heck according to his principles of free thinning.

Species.	*Age on establishment.*	*Present age.*	*No. of perfect stems in Classes 1 to 3. per acre.*	*Total No. of stems in Classes 1 to 3. per acre.*	*Percentage of perfect stems in Classes 1 to 3.*
Beech . . .	59	83	10	80	12·5
Beech . . .	81	101	28	78	36·0
Ash . . .	48	77	9	85	11·0
Spruce . . .	40	56	183	229	80·0
Silver fir . .	42	58	154	172	90·0

It must be realized that the broadleaved plots in particular were already fairly old at the time of establishment, and it is probable that if taken in hand earlier, the system would have produced more perfect stems, but even allowing for this, the proportion of such stems in the beech and ash plots is remarkably low as compared with the conifer plots. It is apparent in the beech and ash that Heck has had to be content with a large majority of second-grade stems; in the conifers on the other hand the numbers conform closely with his requirements. The extremely rigid definition of Heck's *alpha* grade is an important factor in considering the data; most foresters would probably be well content with the appearance of the majority of the second-grade stems; in the ash plot these comprised the whole of the remaining trees in the upper canopy, i.e. there were no really badly shaped trees remaining.

A later section of the book deals in an interesting manner with the thinning of all the major species after the principles of free management. Heck's remarks on the treatment of oak, Norway spruce, and Douglas fir, are of especial interest to British foresters. In each case pruning of the selected stems plays an important part in the procedure. It is, perhaps, worth noting that the author rejects all the patent types of pruning tools in favour of the hand saw and short ladder.

A summing-up in the form of no fewer than 160 propositions enables a rapid survey of the main contents of the book to be made.

In the interest of truth it must be admitted that the arrangement, as well as some of the matter, of the book leaves a good deal to be desired. Repetitions are numerous, and

at times irritating, while one lengthy section on the influence of weather conditions on increment, though interesting in itself, has no discoverable bearing on the main theme. The style is somewhat diffuse, the distance separating the noun from its relative verb at times verging on the astronomical. But these are minor matters: it is the combination of originality of outlook with length of practical experience which go to make this book the important contribution which it is to the practice of forestry. We are convinced that no forester could fail to keep his interest in the theme or help making the resolve in future to search out these elusive *alpha* stems, the selection and nurture of which are so much the concern of the author.

As to the application of free thinning to British conditions, our exceptionally favourable soils and climate introduce a danger probably lacking in the forests of which Heck has had experience, namely the risk of producing excessively wide-ringed and thus low quality timber on the final stems of the crop. This is a factor to be considered especially in the case of such species as Douglas fir and Sitka spruce when planted on optimum sites. But much may be learned from Heck's method of thinning as far as our poorer sites are concerned.

Die Stoffbewegungen in der Pflanze. Ernst Münch. Fischer, Jena 1930. Pp. iv+234, roy. 8vo, 30 figures in text. Price Rmk. 13.50.

Review by R. N. Aldrich-Blake.

RINGING experiments have been repeated frequently from Malpighi's time up to the present day. Twigs from which a complete ring of all tissues outside the cambium is removed remain alive; and cambial activity is stimulated above the ring. But if the main trunk of a tree be girdled below the lowest branch, and all adventitious buds developing below the ring be removed, the tree dies; unless it be one of those tropical species resistant to girdling, whose behaviour has not yet been explained. The results obtained from trees of temperate regions led botanists to the conclusion that the phloem is the conduit for descent of materials synthesized in the leaves.

During the last decade the accuracy of this generally accepted story was questioned, owing to the lack of a satisfactory explanation of the mechanism of transport in the phloem. Birch-Hirschfeld found that lithium salts, introduced through leaves, moved downwards in the phloem at a rate slower than that to which carbohydrate translocation must attain. Dixon calculated that a leaf could not export its daily output of carbohydrates via the phloem if diffusion alone were responsible: and thought that sugars might descend in the outer layers of wood, which are generally injured by ringing. Maskell and Mason, whose recent studies on carbohydrate distribution in the cotton plant are not mentioned by Münch, concluded that sugars are carried in the phloem by a process more rapid than diffusion, but analogous thereto. Thus this book appears at a time when some botanists think that the phloem is merely a conduit for growth hormones; when the majority accept the time-honoured view that carbohydrates travel thereby; but when none have a satisfactory explanation of the propulsive mechanism.

New evidence is marshalled in favour of carbohydrate transport in the phloem. If two longitudinal incisions are made in the bark of a tree, and the intervening tissue is prized off at the cambium and isolated from the underlying wood by a rubber sheet, the phloem remains healthy, and new wood is eventually formed on the inner side. Considerable quantities of phloem sap can be collected from flaps of bark and phloem connected to the tree only at their upper ends. Strips of willow bark thus isolated produce

roots before any xylem is regenerated, an observation for which priority should be accorded to Snow. Cambial activity is stimulated in regions where the wood is killed up to the cambium by fungi or by injected poisons. Hence it would appear that the cambium does not normally draw on the transpiration stream for nourishment. The increased growth is due to the retention of all solutes in the phloem sap by the cambium, through which a proportion passes in the healthy plant to provide the reserves laid down in the living tissues of the wood.

Diffusion is patently inadequate to account for the movement of carbohydrates in the phloem. Sugars synthesized in a leaf would reach a root tip 33 feet distant in 250 years: whereas calculations based on the annual increment below the crown, the area of sieve-tube, and the concentration of the contained sap, indicate that phloem sap must descend at an average rate of several decimetres per hour.

Münch's novel hypothesis of Druckströmung, or mass movement under pressure, is illustrated by a physical model. A bladder whose wall is readily permeable to water, but relatively impermeable to sugar, is filled with a strong sugar solution, and enclosed in a bag of limited elasticity whose wall is readily permeable to both water and sugar. This apparatus, *A*, is connected by a tube to another, *B*, similar in all respects save that the contained sugar solution is more dilute. When the two bladders are immersed in water they act as osmotic cells, and draw in water, which is forced into the connecting tube as soon as the limits of elasticity of the outer bags have been reached. But the pressure developed in the apparatus *A* overcomes that developed by apparatus *B*. There follows a mass movement of solution from *A* to *B* through the connecting tube; while water is forced out of *B*, and a current of water flows from *B* to *A* in the water-bath. Such a circulation continues until the sugar concentrations in the two cells are equalized.

The semi-permeable bladders are comparable to the plasma membranes of living plant cells, the permeable enclosing bags to the cellulose cell walls. Apparatus *A* represents a cell in which soluble carbohydrates are produced, a photosynthetic leaf cell, or a wood parenchyma or ray cell during the spring hydrolysis of starch. Apparatus *B* corresponds to a cell in which soluble carbohydrates are converted into insoluble osmotically inactive materials, into cell-wall substance in primary and secondary meristems, or into reserve starch in wood parenchyma, rays, or fruits. The connecting tube represents the viaduct of the phloem sap, the parenchymatous cells intervening between the cells in which soluble carbohydrates are produced and the sieve-tube terminations, the sieve-tubes themselves, and a second chain of parenchymatous cells at the end of the journey. Finally, the reverse current of pure water in the water-bath is matched in the plant by water which joins the ascending transpiration stream, after depositing its carbohydrate solutes in cambium or rays. The old idea of a circulation of sap reappears in a new guise.

In the physical model the circulation ceases when the osmotic gradient is lost; but in the plant the gradient is maintained so long as soluble carbohydrates are produced in one place and used in another, and turgid leaf cells pump the sugars to the tissues wherein they are used. Birch-Hirschfeld found that lithium salts moved sluggishly in the phloem because they plasmolysed the leaf cells and thus destroyed the pump.

There is definite evidence that phloem sap is transported under pressure in several species of tree: for drops of sap are expelled from severed sieve-tubes; and such exudation is prevented if another incision is first made higher on the stem. The wood must not be injured: since the transpiration stream absorbs the drops by virtue of the tension in which it is held.

It has always been difficult to visualize how sugars are exported from leaf cells, whose

turgidity depends on the relative impermeability of their plasma membranes to sugars. But Münch points out that the sugar solutions need never traverse an outer plasma membrane if they travel in the parenchyma via the plasmodesma. These protoplasmic connexions, which are found between nearly all adjoining living cells, are very fine, it is true: but a relatively slow rate of transport suffices here, owing to the large size of the 'catchment area'. The rapid stream required in the sieve-tubes is made possible by their structure. Once the solution has passed through the inner plasma membrane of the sieve-tubes it can flow freely throughout the phloem system, restricted in rate only by the relatively wide sieve pores.

Movement of soluble carbohydrates in the phloem is not of necessity downward: for phloem sap always flows from the source to the sink of soluble carbohydrates. Novel ringing experiments indicate that phloem sap moves upwards to bursting buds, and upwards or downwards to maturing fruits, as the case demands.

This memorable work, which ends with an interesting historical review, will probably become a classic in the literature of plant physiology. The results of future work stimulated thereby may necessitate modifications in detail of the new theory; but they will probably substantiate the broad outlines, which admirably fit the present known facts.

The Plasticity of the Root System of Corsican pine in early Life. By R. N. Aldrich-Blake, M.A. *Oxford Forestry Memoirs*, no. 12, 1930.

Review by Prof. J. H. Priestley.

THIS interesting paper includes the results of studies in progress since 1923, but such is the complexity of both the practical and scientific problems involved that the results, though very valuable and suggestive, can only be regarded as preliminary.

The Corsican pine has proved very difficult to establish in plantations in Great Britain, so that the author has taken up, for the Forestry Commission, an intensive study of the behaviour of the root system of the seedling under various conditions of growth in the nursery or when sown directly in the plantation.

We know as yet very little about the morphology of the root system of the tree, and the section of the paper dealing with this problem makes a distinct contribution in a field of work which is necessarily very laborious and time-consuming. Of recent years data on these subjects have been accumulating, especially in horticultural literature (see for instance V. A. Kolesnikov, on the root system of fruit trees, *Journal of Pomology and Hort. Science*, viii. 197–209, 1930) and every new contribution only deepens the impression that fundamental studies on these lines will give most help in the end, in dealing with many practical problems.

An interesting point is suggested by the ingenious study in this paper of the order of appearance of successive root primordia. They appear, of course, in acropetal order, but, in a tetrarch root, the next lateral apex to emerge is not usually found opposite the preceding one but more usually emerges opposite one of the adjacent protoxylem groups. When lateral root meristems emerge, therefore, they do not obey Hofmeister's rule, which seems to be the fundamental developmental procedure governing the successive emergence of leaf primordia at a shoot apex. The laws governing leaf emergence are the subject of a vast literature; this paper underlines the significance of our lack of knowledge about the emergence of root initials, as it would appear that, if the upper inches of the tap-root system were better furnished with vigorous secondaries, bearing in their turn a crop of vigorous tertiaries, most of the problems in the way of establishing the Corsican pine would vanish.

The author distinguishes very clearly between four different types of roots or root regions: (1) the tap root or radicle, (2) mother roots, usually diarch, relatively short and freely clothed in branches, (3) pioneer roots with expanded stele, more groups of protoxylem and with vigorous elongation growth at the expense of aborted branches, and lastly (4) small branches dichotomizing early into monarch rootlets heavily infected with mycorhiza. The 'pioneering' habit carries a large part of the root activity in this tree down to unexpected depths at an early age. Sowing in the plantation having so far proved a failure, the success of transplantation seems likely to depend upon keeping the root system of the slower growing 'mother root' type well endowed with branches. Root pruning in the nursery bed was attempted, cutting either the tap root or the secondaries, and the results may be slightly beneficial in the production of additional branches. The reviewer has seen this plan of cutting the tap root in regular use by Mr. Corbett, the forester to the Pacific Lumber Co., in his nursery of redwood (*Sequoia sempervirens*) at Scotia, California. Careful observations in the Corsican pine seem to show definitely that the value of transplanting is not to be attributed to the production of more branches in the upper part of the root system, although undoubtedly transplanting means very rigorous destruction of the lower part; the success of the process undoubtedly lies in the salutary check given to shoot growth, which in view of the slow-growing habit of the seedling in transplantation, is not the most desirable way to bring about its survival if others could be found. The author has tried the effect of humus and also of nitrogen fertilizers in the nursery, but though more vigorous growth of seedlings is thus obtained, root growth gains in root length not in number of secondaries and short absorbing branches useful when transplanting.

The whole problem affecting the type of root growth in the plant is very fascinating. Many observations, in addition to those of Brenchley and Jackson which are quoted, draw attention to the existence in the same plant of two types of root, one branching freely, the other of different growth habit and unbranched. In *Thladianthus* and in some monocotyledons the unbranched region has a dilated stele and is generally thickened, whilst the narrow root regions branch freely.

In the strawberry and the apple, the different types are formed at different seasons; in fact many horticultural observations stress the significance of these different types of root. The author seems inclined to think that the addition of any other mineral nutrient might be expected, like nitrogen, to favour shoot growth relatively to root growth, but in view of some of the recent horticultural experience with cultures of fruit-trees, potash and phosphate manures might prove worthy of trial in the nursery.

PRIESTLEY: 'Studies in the Physiology of Cambial Activity'. *New Phyt.*, 1930.

Review by R. N. ALDRICH-BLAKE.

IN the past few years a considerable amount of research on cambial activity has been done at Leeds: but this work is being published separately; and is mentioned in the present series of papers only in so far as it is relevant to the discussion of the already known phenomena, which are treated, in many cases, from entirely new and very interesting aspects.

Part I. *Contrasted Types of Cambial Activity. Pp.* 56–73.

The cambium of the conifer is compared with that of the hardwood with simple timber structure, with that of the typical hardwood, and with that of the hardwood with stratified cambium.

Bailey's studies on *Pinus Strobus* show that the periphery of the woody cylinder increases a hundredfold between the ages of one and sixty years: while the portion occupied by the fusiform initials expands only sixtyfold, owing to conversion of fusiform initials into ray initials by transverse divisions. The average tangential diameter of the fusiform initials increases from 16 μ to 42 μ, their length from 870 μ to 4,000 μ, and their number in cross-section from 724 to 23,000, i.e. about thirtyfold. It is generally agreed that the fusiform initials always multiply by transverse divisions, followed by readjustments of the daughter cells in which the new transverse wall becomes oblique and finally radial. The peripheral increment here mentioned would be secured if each of the original fusiform initials divided transversely once in fifteen years. In the conifer all the tracheids cut off in one tangential series vacuolate and lignify together, without appreciable elongation: and the plastic fusiform initials, thus subjected to a pressure which increases with age, respond by the recorded increases in length and tangential diameter.

There are no true vessels in some primitive hardwoods; and in these the cambial cells are of the same order of length as in the conifer. The cambial cells are very short, about 250 μ, in those hardwoods in which they are 'stratified' in regular horizontal rows, resulting from the radial divisions by which peripheral increase is secured. They average 410 μ in length in the majority of hardwoods, and do not increase in length as the tree matures: because the pressure which is borne by the cambium in the conifer is here transferred to the fibres, which are still plastic at the time that the vessels are vacuolating and increasing enormously in cross-section. Thus the fibres are compressed to about half their original tangential diameter, and elongate till they are several times the length of their parent cambial cells.

Part 2. The Concept of Sliding Growth. Pp. 96–139.

In the old and scarcely challenged theory of sliding growth it is assumed that the walls of the fusiform initials of the conifer, and of the differentiating fibre of the hardwood, slip past one another as these cells elongate. Any such movement would be impossible once the middle lamella was set to a hard cement; and it would involve a shearing of all the plasmodesma, or protoplasmic threads connecting neighbouring cells: so that if slip occurred at an early stage in differentiation there should be no pits at all; while if it occurred later the pits in neighbouring cells should not correspond, as in fact they do.

The greatest slip, in the conifer cambium, would be on the radial walls; since increase of cambial periphery is attained by originally transverse walls becoming radial. Yet it is on these walls that pits are found in the mature tracheid. For the general lack of pits on tangential walls a slight slip may be responsible. The gradual vertical shift of Sanio's rims in radially successive tracheids indicates that the radial walls of the fusiform initial on which they were borne have moved vertically in time, but without any slip: and Sanio's trabeculae also yield evidence against the theory of sliding growth.

In the hardwood tree there must be some slip between vessels and fibres, since the latter elongate while the former do not; and the vessel segment initial in contact with six fibres may grow till it borders on thirty. Frequently pits do not correspond between vessel and fibre: but they do between fibre and fibre; indicating that the plasmodesma cannot have been broken, and that a block of fibres between expanding vessels must deform and elongate as a cohering whole. This elongation must be downwards; since cambial activity in the hardwood spreads basipetally from the buds; and only by sliding growth could the plastic fibres extend among the more fully differentiated elements above. Kostychew maintained that the number of fibres in cross-section did not increase,

during differentiation, in proportion to the increase in their length: and this finding is quoted as evidence against the occurrence of sliding growth. But it is difficult to visualize how fibres can elongate without increasing in number in cross-section. In the scheme of downward elongation here set forth there would surely be a surplus of fibres, unless there were a progressive basipetal decrease in the number of fibre initials produced?

The theory of sliding growth undoubtedly fails to account for the facts in both conifer and hardwood. A consideration of the readjustments of walls after division of apical meristem cells helps in the appreciation of the phenomena in the fusiform initials, which are essentially meristematic cells elongated under pressure. The theory of mutual readjustment by growth of cell walls without slip, which is aptly christened symplastic growth, explains the phenomena in the conifer cambium satisfactorily, and in the elongating fibre, save for the apparent difficulty mentioned.

Part 3. The Seasonal Activity of the Cambium. Pp. 316–54.

The difficult question as to how far the rhythm of cambial activity is controlled by internal factors is discussed: and the correlation of cambial rhythm with rhythm in other growth processes is emphasized. More critical data are required for the conifer: but in the hardwood it appears certain that cambial activity is initiated in the spring in both terminal and lateral buds, and spreads thence downwards to the base of the tree. Experimental evidence shows that buds are normally essential for initiation of cambial activity: but the theory that they exercise their influence by secretion of growth hormones is not favoured. Both initiation and cessation of cambial growth are thought to be controlled in the main by the water relations of the cambium. Air can be seen in the intercellular spaces of the cambium during dormancy, but not during the growth period.

Sledge: 'The Rooting of Woody Cuttings considered from the standpoint of Anatomy.' *Journ. of Pom. and Hort. Sci.*, 1930, pp. 1–22.

Review by R. N. Aldrich-Blake.

At the base of woody cuttings the phellogen is responsible for most of the callus formation; but roots arise in the neighbourhood of the cambium. It is well known that the absence of buds on cuttings made in winter has a deleterious influence on root formation; and that cambial activity normally spreads downwards from the buds. Thus there seems to be a connexion between cambial activity and emergence of roots.

In cuttings of apple, Forsythia, privet, and sycamore, struck during winter when the cambium was dormant, one wave of cambial activity spread downwards from the buds, another upwards from the lower cut surface; and all save apple rooted well. Disbudded cuttings failed to give very conclusive results, since new buds were formed. But on internodal cuttings, taken during cambial dormancy, no new buds arose: and in these the upward-spreading wave of cambial activity was restricted to a few millimetres above the wound surface; there was no basipetal spread of cambial activity from above; and but one out of many produced a root.

It is maintained that cambial activity and root production are not necessarily dependent on the presence of buds. Root development can be stimulated by the cambial activity initiated at the wound surface: but in internodal cuttings this activity spreads upwards for so short a distance that it seldom reaches a root germ. In the normal cutting root development is stimulated by both waves of cambial growth, and roots therefore arise over a considerable length of the cutting. Both the normal downward wave of

cambial activity and the wave spreading upwards from the wound surface are thought to be initiated by injection of the intercellular spaces of the cambium with sap: and hormonic theories are rejected. But Haberlandt's theory of wound hormones rests on good experimental evidence: and it should be mentioned that Went has recently provided excellent evidence for the existence of substances capable of stimulating root formation in cuttings of Acalypha.

COCKERHAM: 'Some Observations on Cambial Activity and Seasonal Starch Content in Sycamore (*Acer Pseudo-platanus*).' *Proc. Leeds Phil. Soc.*, 1930, pp. 64–80.

Review by R. N. ALDRICH-BLAKE.

THE conclusions are based on a close study of both stems and roots of thirteen twenty-year-old trees felled at approximately monthly intervals between May 1928 and April 1929.

A full description of the resting cambium is followed by an account of its activity throughout the year. After a preliminary swelling of the cambial cells, evidenced by the slipping of the bark, differentiation of phloem began in the latter half of March, and was followed in late April by xylem differentiation, which spread basipetally, accompanied by a retardation of phloem differentiation, from the buds as far as the proximal portions of the root system. The first vessel segments were produced by the swelling and thickening of undifferentiated elements cut off from the cambium the previous year. Xylem differentiation ceased, as it began, basipetally; and the annual ring was complete at the base of the stem by mid-August. A second period of phloem differentiation culminated in September, and continued till November in the lower part of the trunk. It is amazing to learn how short may be the life of a sieve-tube. In the present trees the spring formed sieve-tubes began to collapse in July, and were finally crushed in November: while those cut off in the autumn matured over winter by a deposition of callus over the plates, and collapsed in March when cambial activity was resumed.

The wave of cambial activity initiated in the buds never reached the distal portions of the root system, in which a continuous but very sluggish growth was maintained throughout the year.

In all tissues and organs starch increased from nil at the end of May to a maximum between July and September; decreased till October, and remained at a low level in all tissues of the upper part of the stem throughout the winter, while rising again gradually at the base of the stem and in the roots. By the end of March it had reappeared in all tissues and organs; but disappeared once more during the burst of growth in spring. The author seems rather puzzled by the loss of starch in autumn, and its reappearance in early spring. But the winter of 1928–9 was cold; and the records agree with expectation. For it is well known that starch reserves are converted into sugars at low temperatures, and sweet potatoes furnish a classical example of this phenomenon.

'Observations on the Parasites of the Pine-Shoot Moth, *Rhyacionia* (*Evetria*) *buoliana* Schiff.' By W. H. THORPE, M.A., Ph.D., Imperial Institute of Entomology. *Bull. Ent. Res.*, vol. xxi, pt. 3, pp. 387–412. Oct. 1930.

Review by R. N. CHRYSTAL.

THE Pine-Shoot Moth (*Rhyacionia* (*Evetria*) *buoliana* Schiff.) is one of those Lepidopterous pests which, like the Gipsy and Brown-tail Moths, has gained a cosmopolitan notoriety, its capacity for destruction having apparently increased in the United

States and Canada during the past few years. The insect is well known in this country as a pest in young pine plantations and special studies on its life history and forest relations have recently been started in the Scots-pine areas of H.M. Forestry Commission in East Anglia, where the prevalence of the insect had given rise to anxiety. This paper, which deals with the parasites of the moth, did not originate as a result of these studies. It is a review of some work which was recently carried out by the Parasite Laboratory of the Imperial Institute of Entomology at Farnham Royal, Bucks., on the parasites of the insect, the practical object of which was to discover and collect suitable parasites for shipment to Canada for colonization in those areas where the insect has established itself as a pest.

The paper, which in the author's own words—'is little more than a summary of some aspects of the work'—gives the reader a very clear idea of the vast amount of work which was done on the parasites by the Farnham House Laboratory. Twenty-eight species, collected during the course of the work, are listed and discussed, some of which have never been previously associated with *buoliana*, whilst others are new to Britain. Three of the principal species were shipped to Canada during the summer of 1928, and it is satisfactory to note that as a result of examinations made in the summer of 1929 in those Canadian localities which had been selected for colonization, two of the species were found to have successfully survived the severe Canadian winter. The paper appears at an opportune moment, for, as stated above, a start has already been made on a thorough study of the insect under British conditions. In this connexion it cannot be too strongly emphasized that if we are to get a true picture of the forest relations and importance of *R. buoliana* to the Scots pine in this country, all aspects of the problem must be thoroughly studied. The parasite complex is one which even though it opened up no royal road to the control of the insect, might still provide us with valuable data, and stress the importance of other factors which would lead to some system of prevention or control.

Finally, some mention must be made of the morphological studies of the heads of last-stage larvae of Ichneumonidae and Braconidae, described on pp. 403–9. The author contends 'that a species of insect cannot be completely described, nor its systematic position settled, until the larval characters are as well-known as those of the adult'. He supports this dictum, which is very sound, by a valuable comparative study of the mouth parts and tentorial structures in one species of Braconidae (*Orgilus obscurator* Nees), five Ophionine Ichneumonids of the genera *Omorgus*, *Eulimneria*, and *Cremastus*, and three Pimplines of the genus *Pimpla*. He expresses the hope that the characters used may be found applicable to the larvae of the Parasitica as a whole, and here he opens up a wide field of investigation in which he has provided a valuable basis for further work.

Effect of Time of Felling upon the Durability of Timber.
Untersuchungen über den Einfluss der Fällungzeit auf die Eigenschaften des Fichten- und Tannenholzes. Part 2.[1] *Der Einfluss der Fällungzeit auf die Dauerhaftigkeit des Fichten- und Tannenholzes.* By Ernst Gäumann. Nr. 6 Beiheft zu den Zeitschriften des Schweizerischen Forstvereins. Bern, 1930.

Review by W. P. K. Findlay.

As a further contribution to the comprehensive study of the effect of time of felling upon the properties of spruce and silver-fir wood, which is being carried on at Zürich, Professor Gäumann has now published an account of his researches upon the

[1] Part 1 was reviewed in Forestry, iv, no. 2, p. 137.

influence of the time of felling upon the durability of these timbers, of which he gave a brief account at the International Botanical Congress at Cambridge last year.

Amongst those engaged in practical forestry it has long been stated that wood from trees felled in the spring and summer is more liable to decay than that from trees felled in autumn and winter, but scientific workers have been inclined to believe that the less amount of decay which takes place in the latter is due to the fact that wood felled in the winter has time to dry out somewhat before conditions become favourable for fungus growth. The author set himself the task of determining the magnitude of the variations in the durability of timber felled at various seasons and also whether there was any real difference in the decay-resisting powers of the wood substance itself at different times of the year.

A comprehensive series of experiments which included both field and laboratory tests was planned, and carried out over several years. Great care was taken in the selection of the trees, which were felled in different months, in order that they should be as similar as possible.

The field experiments fall into two groups: in the first series logs 1 metre long were exposed in the open, and in the second squared pieces of wood about 1·3 metres long and 10 cm. square were half-embedded in the earth.

Four logs of each species were prepared at each felling, of these two were barked and two were left with the bark on, and in each instance one of each pair was placed directly upon the ground and one was raised upon a frame 15 cm. above ground level.

After one year striking differences were observable in the appearance of the logs felled at different seasons: those felled from September to January (inclusive) were resistant to decay and no fungus fruit bodies were produced upon them, while the August and February fellings were much less resistant and the logs felled in May and June showed the most fungus decay and also split badly. A definite correlation was seen to exist between the time of felling and the resistance of the logs to decay.

In general the logs raised on supports decayed somewhat more than did those lying on the ground, but, of the supported logs, those with the bark on rotted very much more than those which had had the bark removed and also showed more markedly the varying rates of decay of the different fellings.

The amount of attack by wood-boring insects was also noted; only those logs which had been left with the bark on were attacked. *Xyloterus lineatus* appeared only on wood felled from September to February (inclusive) and *Tetropium luridum* on the April, May, and June fellings. The attack by insects differs of course from that of fungi, in that the infesting agents (female beetles) are only active during a certain season, while fungus infection is always present.

In the experiments with the squared pieces of wood the amount of decay of the pieces was estimated by cutting out the portion near ground level and determining the amount of material that could be extracted by various solvents. The results obtained tallied closely with the observations on the round logs, the decay occurring in the wood from the May felling being very much greater than in the wood from trees felled in the autumn and winter. The wood of the squared pieces differed from that of the logs in that the living cells died rapidly after felling and the wood did not continue to undergo the changes due to the living activities which went on for some time in the logs after they had been cut, hence the curve for the decay of the pieces from the spring fellings is somewhat more regular than that for the logs.

The laboratory experiments were carried out upon sawdust prepared from the sap- and the heartwood of the trees immediately after felling; from wood that had been

seasoning for one year under cover; and from material weathered in the open for one year. Weighed quantities of sawdust were placed in flasks with a certain amount of water and after sterilization by a mild steaming were inoculated with a pure culture of *Merulius lacrymans*, *Polyporus vaporarius*, *Coniophora cerebella*, or *Lenzites abietina*. A large number of cultures for each fungus and for each type of wood were set up so that the results could be treated statistically. Samples were analysed after three, six, and twelve months' exposure to the fungi, and the losses in weight were determined. The amount of decay, which was calculated from the loss in weight plus the total amount extracted by various reagents from the woods, is expressed as a percentage of the original dry weight and the results are shown graphically.

In every experimental series, i.e. for each fungus on each type of wood, the winter-felled material was quite definitely more resistant to decay than the spring and summer-felled under constant conditions of temperature and moisture. The reason why both heart- and sapwood of spruce and silver fir show this widely varying resistance to decay at different seasons, was then sought. The amounts of hexoses and other water soluble substances occurring in the wood, were determined during each month of the year, but the correlations between these amounts and the percentages of decay were not close and these substances could not be regarded as exerting a dominating influence. Contrary to general opinion, no relation could be found between the varying amounts of resin and the susceptibility to decay.

The condition of the substances composing the cell walls at various seasons was then investigated after the different periods of exposure to the fungi. A certain connexion between the decomposition of the pentoses (xylan) and the amounts of decay was noticeable, but this was chiefly in the heartwood. The influence of the relative solubility of the lignin was slight and limited to a few cases only; it is suggested that its action may be chiefly one of protecting the cellulose by acting as a sort of incrustation on it. When, however, the decomposition of the cellulose was considered, an extremely close correlation was discernible between this and the amount of decay, and the author concludes that the seasonal variation in the resistance of these woods to decay is due chiefly to the different colloidal condition of the cellulose in the cell walls at different seasons.

This conclusion is somewhat strengthened by the results of the experiments on the seasoned and on the weathered wood. The sawdust from the wood seasoned under cover was decayed very much less rapidly than that from the freshly felled wood, and the differences between the various fellings were much reduced, while in the case of the material exposed to the weather, these differences disappeared completely. The differences in the rates of attack of the different species of fungi were greatly reduced and the durability of the heart- and of the sapwood also became more nearly the same.

From a practical point of view these findings are valuable; spruce or silver fir felled in spring are at least twice as susceptible to dry-rot as autumn-felled if used in an unseasoned condition. So far as resistance to decay is of any importance spruce and silver fir should not be felled during the period between the rise of the sap and the completion of the formation of the annual ring. Seasoning greatly reduces the actual susceptibility of the wood substance to decay as well as bringing (at least temporarily) the moisture content of wood down to a point unfavourable for fungus growth. The effect of seasoning on the colloids of the wood is apparently in part irreversible and seasoned wood can never become so readily attacked as freshly felled.

Professor Gäumann is to be congratulated on the completion of so careful and laborious a piece of work which has been carried out with due regard to statistical accuracy, and which takes cognizance of the many sources of error to which experiments on wood

are liable, and he has definitely established the difference in decay resistance of wood felled at different seasons. There are current so many general impressions regarding the properties of timber that it is refreshing to read such work which settles, beyond doubt, the question in dispute, and this paper must be regarded as one of the most important contributions to timber pathology in recent years. His work refers only to the wood of *Picea* and of *Abies* in Switzerland, and it will be of great interest to know whether the same conclusions hold for other trees, especially for deciduous trees in which one would expect any rhythmic yearly changes to be greater than in evergreen conifers.

The Use of Home Grown Larch Poles for Transmission Lines. Forest Products Research Bulletin, no. 8. H.M. Stationery Office, London. 1931. Price 2*s*.

Review by John T. Smith.

BULLETIN No. 8 issued by the Forest Products Research Laboratory claims to have found a method of treating home-grown larch poles which will render them suitable for use as telegraph, telephone, and power transmission lines. The method is to fell the trees (October suggested), peel, *incise*, and pile them for seasoning, and when they are air seasoned to a moisture content of 25 per cent, to creosote them by the Bethel or full cell process. By incising is meant the piercing of the surface of the poles with a short broad knife, making a number of cracks in the direction of the grain of the timber so that the subsequent drying checks are influenced and severe checking thus reduced. It is claimed that the poles creosote more thoroughly after such treatment, and while incising slightly weakens the poles, they are still 30 per cent. stronger than imported Scots pine of the same dimensions and the same moisture content. This is an important Bulletin and covers research work since 1928, and it is the first bulletin of the laboratory to apply the results of research to an individual use of the timber. Full details of the experiments are given in the bulletin, which comprises some 25 pages and 11 full-page illustrations and diagrams. These bear out the claims of the method in question.

No information is given in the bulletin as to the cost of the treatment prescribed. To ascertain the cost of incising, the reviewer conducted an experiment in a larch plantation in the west of Scotland. The instrument used to incise the poles was a $\frac{3}{4}$-inch chisel driven $\frac{3}{4}$ inch into them with a hammer. The incisions were staggered to avoid subsequent straight-line checking. A pole say 30 feet long by $6\frac{1}{2}$ inches diameter at top by $9\frac{1}{2}$ inches diameter at butt required approximately 90 rows of incisions averaging 16 per row, thus 1,440 incisions. It was found that the incisions could be made at the rate of 40 per minute, and it would therefore take 36 minutes to make all the incisions. Changing position and turning the pole would add another 9 minutes, making 45 minutes in all. Peeling can be done in one-third of this time. The cost of incising may therefore be taken as three times the cost of peeling, but a mechanical method can no doubt be devised to reduce the time taken. It would be useful to compare this cost with the cost of drying the poles unbarked, a method of avoiding check which is unfortunately dismissed, because two additional years might be required to reduce the poles to the proper moisture content before creosoting.

In a publication of this kind one would also like to have found an attempt to draw upon the experience and research (if any) of other countries.

It is presumed that typical specimens drawn from a true larch zone in this country have been used in the course of the experiment. The poles referred to in the bulletin

were drawn from Tintern Forest, Monmouthshire, but no details are given of exposure or soil.

There is no doubt about the urgent need for an economic method of overcoming the mechanical peculiarity of Larch in warping and twisting. The Post Office or other large user of poles might be *officially* persuaded to continue the experiments by putting them into practical use. A private offer on the part of an individual firm has already been declined. The additional strength proved in larch poles and their greater durability will no doubt justify the additional price which must of necessity be paid for them.

Our Catkin-bearing Plants. An Introduction. By H. Gilbert-Carter, Director of the Cambridge University Botanic Garden, and University Lecturer in Botany. 61 + x pp., 16 plates. Clarendon Press, Oxford, 1930. Price 4*s.* 6*d.*

Review by J. Burtt Davy.

THIS little book deals with those British trees known collectively as the Amentiferae or Catkin-bearers, which include the Alders, Beeches, Birches, Hazel, Hornbeam, Oaks, Willows and their allies. The book is of convenient pocket-size, evidently intended as an adjunct to a country ramble, and for use by those who do not know their species. The plates showing the differences between the pedunculate and the durmast oaks are useful, but some indication of the forms taken by the hybrid segregates would have been helpful. It is doubtful whether the novice will be able to identify some of the willows and elms from the very brief descriptions; plates showing the characteristic differences in leaf-outline of the several species in these critical genera, would have been of distinct advantage, more so, indeed, than the plate purporting to illustrate *Ulmus hollandica* Miller.

Révision du Genre Abies. By H. Gaussen and Th. Viguie, of the Laboratoire Forestier, Faculté des Sciences, Toulouse. In *Bulletin de la Société d'Histoire Naturelle de Toulouse*, tome 57. 369–434 (1928), and 58. 245–564 (1929), 386 pp., well illustrated with many detail drawings.

Review by J. Burtt Davy.

THIS is an original revision of the genus *Abies*, which promises to be of value to Forest Officers; the authors have recognized the need for illustrations, showing the variations of form in leaf-apex, bract, and cone-scale in one and the same species; the figures are very detailed, and show thought and care in their selection and preparation. It is a relief to find the name *Abies pectinata* retained for the Silver fir, in place of *Abies alba*, which has been in use in French Floras for some years; the reason assigned for this is that *Abies alba* Miller (*pro parte*) is a *nomen confusum*.

The book may be obtained direct from Professor Gaussen, Faculté des Sciences, Allée Saint-Michel, Toulouse, France; the price is not stated. It seems likely that it would obtain a larger circulation if issued as a volume separate from the Bulletins of the Society, and through a regular publishing house, but the figures may have made this impracticable as business firms seem to be shy of undertaking the publication of illustrated monographs and floras. Those interested in the firs would do well to obtain copies while they are obtainable without breaking into sets of the Bulletin.

Une Nouvelle Espèce de Sapin, Abies pardei *Gaussen*, in *Bull. Soc. d'Hist. Naturelle de Toulouse*, 57 (1928), 357–66, cum tab. (published March, 1929).

Review by J. Burtt Davy.

AMONG the old trees in the Arboretum of Barres, trees certainly planted before 1875, are three firs catalogued as *Abies numidica*. Among these one has been found which differs from *A. numidica* in the densely pubescent, often blackish, branchlets; the central position of the resin canals; the shape of the cone-scales, which are longer than their breadth; and in the bracts which exceed the middle of the cone-scale and are exserted. This species has been described and published by Professor Gaussen under the name *Abies pardei* Gaussen. Next to *A. numidica*, the species to which *A. pardei* approaches most closely is *A. borisii-regis* Mattfeld, of Thessaly; from this it differs, among other things, in the numerous (up to 12) rows of stomata on the upper surface of the leaves on fertile branches; the pointed leaves on the sterile branches; the central resin-canals; and the narrower cone-scales, in proportion to their height. The origin of the new tree is unknown, but M. Gaussen states that it must be a Mediterranean Region species; he suggests that it may have come from north Africa, but points out that Professor René Maire fails to find anything like it in the herbarium at Algiers. An excellent figure, with details, is given.

Professor Gaussen furnishes a descriptive key to the twelve circum-Mediterranean species of Abies. He concludes his interesting paper with a discussion of the origin of these species, from which he concludes that they fall into five groups: (1) Pectinata (*A. pectinata* and *A. nebrodensis*); (2) Nordmanniana (*A. nordmanniana*, *A. bornmuellerianа*, and *A. equitrojani*); (3) Cephalonica (*A. cephalonica*, *A. borisii-regis*, and *A. pardei*); (4) Pinsapo (*A. numidica*, *A. marocana*, and *A. pinsapo*); (5) Cilicica (*A. cilicica*). The affinities of these twelve species, he concludes, are with the Himalayan group of Abies, through *A. cilicica*.

A travers les Forêts de pinsapo d'Andalousie. By A. Barbey. Gembloux, Jules Duculot, 1931.

Review by the Editor.

THIS book by the well-known Swiss entomologist is an uncommon one—a mixture of history, travel, and science—and although *Abies pinsapo* is never likely to be an important forest tree in Great Britain, foresters whose professional interests are not bounded by a utilitarian horizon will enjoy reading it.

The Spanish silver fir was first referred to by an English engineer, employed by King Carlos III, in a natural history published in 1775, but it was Barbey's grandfather, Edmond Boissier the well-known Swiss botanist of last century, who named and described the species, amongst his many other contributions to the knowledge of the Spanish flora. It was this scientific connexion with Spain which led Barbey to explore the mountains between Malaga and Gibraltar, and the present volume is in part a memorial to his distinguished grandparent.

Several of the most important forests in this region are described, and the information recorded considerably extends the knowledge regarding *Abies pinsapo*, the associated *Quercus alpestris* Boiss., and the conditions under which they grow. Unfortunately very extensive damage is being done by the over-grazing of goats and sheep, and the control and limitation of this is an urgent necessity, if these forests are to be saved,

and the disastrous effects of their disappearance are to be avoided. Barbey crystallizes this need in an apt quotation:

Aimez et vénérez, ne tuez pas les arbres;
Un pays meurt, après que ses grands bois sont morts;
Aucun n'est protégé par les splendeurs des marbres
Et, les abris perdus, les peuples sont moins forts.

As one expects from a distinguished entomologist, the insect pests of *A. pinsapo* and *Q. alpestris* are described. He found two species new to science: *Crypturgus barbeyi* Strohmeyer, and *Diorychria aullói* Barbey.

There is a preface by M. Pardé, Directeur des Écoles forestières des Barres. The interest and attractiveness of the book is greatly increased by forty-one beautiful plates.

NOTICES

The Death-Watch Beetle. Forest Products Research Leaflet No. 4. January 1931.

FEW insects have attained greater notoriety in recent years than *Xestobium rufovillosum*, owing to its depredations in roofs of historic buildings. This leaflet outlines existing knowledge and methods of treatment, but much remains to be known, and an investigation is at present being conducted by the laboratory. An appeal is made to architects, builders, and all concerned in the repairs of buildings attacked by the Death-Watch beetle, for untreated timber containing living insects. Arrangements should be made with the Director, Forest Products Research Laboratory, Princes Risborough, Bucks.

Such an investigation must be laborious and long, but on the finding of means of effective prevention and treatment depends our ability to hand on intact some of our most cherished national possessions.

Empire Timbers from Home and Overseas for building and structural Purposes. By Major J. R. Cosgrove. Forest Products Research Leaflet No. 5. February 1931.

THIS leaflet brings together information regarding the most important home and empire timbers. The arrangement is under countries, while the index tabulates the timbers alphabetically. The information includes a list of the uses, methods of treatment, and grades. The leaflet should be of material assistance to architects and others who wish to use Empire products.

Preliminary Report on the Creosoting of Douglas fir Sleepers. By J. Bryan. Forest Products Research Laboratory, Project O. December 1930.

THIS publication deals with methods of treating Douglas-fir sleepers on lines similar to larch transmission poles—reviewed in this issue.

The following suggestions are made:

1. The sleepers should be incised before treatment.
2. The treatment should consist of a high preliminary vacuum of 20 inches for 1 hour, followed by a pressure of 170–80 lb. per square inch until an absorption of 10 lb.

per cubic foot has been attained. This should usually be from 3 to 5 hours. The temperature of the creosote should not be below 100° F. or above 200° F. during time of treatment.

3. Particular attention should be paid to the seasoning of the sleepers so that they shall be in as dry a condition as possible immediately prior to treatment.

Enquête internationale sur la standardisation de la Mesure du Bois sur les différents Modes de Vente du Bois. Institut international d'Agriculture. Rome, 1930.

THIS publication records the replies to a questionnaire dealing with the introduction of the metric system for timber measurement. A uniform system of measurement has obvious advantages, but it can only come when there is almost complete unanimity among the countries concerned. The replies clearly indicate that this is far from being the case, and nothing more is likely to be heard of the proposal for a long time.

USE OF SITKA SPRUCE IN BRITISH AFFORESTATION

BY SIR ROY L. ROBINSON

DURING the twelve planting seasons covered by the operations of the Forestry Commission, Sitka spruce has grown steadily in favour for afforestation operations. The table below shows for various years the number of Norway and Sitka spruces planted in the State forests. It will be seen that while the total has naturally increased with the expanding planting programme there has been a marked tendency to plant more Sitka spruce at the expense of Norway spruce.

Bearing in mind the fact that Norway spruce is a sound and well-proven species in Britain, it is interesting to review the reasons which have led to its partial relegation in favour of the newer exotic spruce.

Year.	*Norway Spruce.*	*Sitka Spruce.*	*Total.*
	Millions	Millions	Millions
1923	2	2	4
1925	5	3	8
1927	5	7	12
1929	4	9	13
1931	7	13	20
TOTAL	23	34	57

As regards the raising of nursery stocks suitable for plantation work there is not much difference to be noted between the two species. Seed of both is readily procurable and stores well, so that there is no especial difficulty in keeping up a succession of plants of the required ages. Sitka spruce seed is perhaps 5–6 times as expensive as Norway, but should yield twice as many plants per pound. Sitka spruce seedlings suffer more from winter frost-lifting and spring frosts, but can readily be protected against both. Both species are ready to line out as 2-year seedlings, but it is more frequently necessary to grow Norway spruce on to 2-year 2-year plants in order to obtain a suitable plant for the forest. The cost of producing 2-year 1-year Sitka and 2-year 2-year Norway spruces consequently works out at much the same figure: approximately 25*s.* per thousand.

Put out under identical conditions there are no differences in planting methods or costs, but Sitka spruce almost invariably starts away quicker, and has often got well into its stride before the Norway spruce is out of the check stage. This is not only a pleasing result in itself, but in a moist country like Britain, where weed growth is a menace to young plantations, shows a considerable saving in favour of Sitka spruce in the total cost of establishment.

Sitka spruce will also establish itself and grow well on sites on which Norway

spruce either checks for a number of years or dies out. Such are certain types of peat, and, even more noticeably, sites exposed to the sweep of sea winds. On the other hand, Sitka spruce suffers more from late spring frosts (though Norway spruce is not immune in this respect), and in occasional bad spells trees up to 10 to 15 feet high have had their leaders killed back. It is also more prone to attack by *Armillaria mellea* on the site of former hardwoods, though rarely more than 10 per cent. of the trees are killed by the fungus. Both spruces suffer in occasional years from defoliation by greenfly (*Aphis abietina*), but as a rule recover rapidly. It is often impossible after the lapse of a couple of years to detect trees which had been almost completely defoliated.

The normal picture then of adjacent plantations of Sitka and Norway spruces aged 6 to 8 years old will be this: the silvery-green Sitka plants average 5 to 10 feet high, rather irregular in growth, but the best trees, and putting on annual shoots 30 to 40 inches long. The dark green Norway spruce are 4 to 6 feet high, more regular in growth, with leading shoots 20 to 30 inches in length. As the plantation gets older the disparity in growth increases. More of the long sappy Sitka shoots get broken from various causes, but the main stem rapidly straightens and in a few years the break cannot be detected.

Viewed from within after the first brushing up and thinning, which may be as early as 15 years with Sitka spruce and not before 20 years with Norway spruce, the Sitka are the more cylindrical and stubs left by pruning the side branches do not, as with Norway, tend to form swellings. In neither case do the side branches fall quickly of their own accord, being probably more persistent in Norway spruce.

Concurrently with the growth of experience in forming new plantations a great deal of information has been collected concerning the productivity of the two species. Details are given in an article which follows, but it is safe to say that as a rule Sitka may be expected to produce at least 50 per cent. more timber than Norway. Nor does there appear superficially to be any appreciable difference in the values of the two timbers. This is an important point which will be discussed in a subsequent article.

A further and very important consideration in Britain is the superior resistance of Sitka spruce to wind. Not only does it appear to be more wind-firm than Norway spruce against storms, but its foliage is certainly more resistant to the persistent westerly winds which sweep over the country. Striking examples can sometimes be found of the two trees growing side by side on the windward margin of an exposed wood: the Sitka vigorous, green, and fully clothed; the Norway stunted, brown, and bare of needles on the exposed side.

Incidentally, it may also be mentioned that in the industrial districts of South Wales, Sitka spruce and Japanese larch are the trees most resistant to damage by smoke.

In sum it may be stated that Sitka spruce is a maritime tree and finds maritime conditions in Britain. Norway spruce is not a maritime tree, and although it does well under most conditions it is not so perfectly adapted to the environment.

The above considerations taken together explain why foresters have increased proportionately the use of Sitka spruce in British afforestation operations. A good case could, in fact, be made out for replacing Norway almost completely with Sitka spruce. It is not intended to allow this to happen. Both spruces are exotics, but the Norway has served a long apprenticeship and proved itself a steady hardworking servant. Sitka is not new to the country, but cannot yet be considered equally 'safe'. So far it has remained remarkably free from serious pests and there is no reason to anticipate trouble. At the same time it appears wise not to put too many eggs into the one basket.

SITKA SPRUCE—ON POOR SOILS AND AT HIGH ELEVATIONS

BY SIR JOHN STIRLING-MAXWELL, Bart.

FOR planters who have to struggle with these difficult conditions, the advent of the Sitka spruce has opened a new era, and definitely extended the limits of economic forestry.

A student who wishes to observe the behaviour of the tree on high and exposed sites cannot do better than visit Dartmoor. There, in plantations at Fernworthy—made by the Duchy of Cornwall and now taken over by the Forestry Commission—he will see the tree growing on windswept hill tops up to 1,500 feet, and be able to compare its growth with that of the Norway spruce planted alongside. The Norway spruce at 12 years of age has reached a height of 6 to 7 feet, but it is yellow and stripped bare on the windward side, and the growth is very slow. On the other side of a ride the Sitka spruce under precisely the same conditions has kept its leaves and deep colour and is making much more rapid growth. The leaders, when gales occur before they have ripened, often get broken or twisted. The plantation is in consequence somewhat irregular and dishevelled. But there is no doubt about its vigour or its ability to produce enough good stems for the final crop. This is on fairly good soil. Sir Roy Robinson, with whom the writer visited Fernworthy, thinks that the Norway spruce will eventually close up and make a good crop, except on the exposed margin. This may well be, as it grows well at Kerry (Montgomery) up to 1,500 feet.[1] But there can be no doubt that the Sitka spruce is the better tree for the site and capable of yielding a much heavier crop of timber in a shorter rotation.

The writer's own experience of Sitka spruce has been gained mainly at Corrour in Inverness-shire at elevations between 1,250 and 1,600 feet. Here, with a rainfall of some 70 inches, snow is a formidable factor. All the spruces and silvers stand up well to the snow. The Sitka, with its long leaders, seems to invite disaster, but disaster never comes, even where the Scots pine is completely crumpled up. The contrast is very striking where Sitka has been introduced to replace the pine. So planted the Sitka gets away very rapidly. The pine has killed out the heather and *Molinia* grass has taken its place. The remains of the pine crop provide invaluable side shelter. Overhead shelter, by the way, can easily be overdone. Sitka will not stand nearly so much shade as Norway. The leaders are occasionally broken by wind on the high slopes, but not to the same extent as on the summit at Fernworthy.

For this kind of site it is now the writer's invariable practice to use Turf Nurseries. The ground to be planted has already been enclosed and drained,

[1] Sir Roy made a careful study of the Kerry Woods which is not so well known to foresters as it should be. It was printed by the Ministry of Agriculture in 1912.

if it needs draining, but it is all more or less covered with peat and quite unsuitable for pit planting. The *Molinia* grows very rank when the pine is opened and small notched plants would be costly to weed. The problem, therefore, is to establish large plants on the surface. At elevations above 1,400 feet such plants are useless unless thoroughly acclimatized.

The turf nursery is designed to meet these needs. Turfs about 10 inches square are turned over in continuous rows on any suitable spots—preferably on wet patches which have anyhow to be drained. 1,500 to 2,000 plants are a convenient number for each nursery. On each turf a 2-year seedling or 2-year 1-year Sitka is planted with a trowel spade, and two handfuls of a compost of basic slag and sand are applied to the roots of each plant. Supposing the turfs are turned over this autumn (1931), the plants will be set out on them in the spring of 1932. They will remain untouched all through 1933. In the summer of 1934, when the new leader is sufficiently firm not to get broken—say in July or August—the plants are moved, turfs and all, to their permanent places. Hand barrows are used which carry six to eight plants. Every fifth plant in every other row is left *in situ* in the nursery which thus becomes part of the plantation.

All this sounds far more elaborate than it really is. The turning over of the turfs takes a very short time. The planting compost is made alongside the nursery and the planting, being so concentrated, is done very quickly. So is beating up, if any is required, which is seldom the case. The plants when moved to their final positions are perfectly acclimatized and accustomed to a peat soil. Unless transferred to worse soil, they are unaware that they have been moved, and there is no check. The seedlings by this time will have caught up the transplants. They are about 2 feet high and require no weeding. If the nurseries are well placed few plants have to be carried more than 30 yards and none uphill.

Let us return from this digression—which readers who have the same job to face, and are tired of planting trees in wet holes and weeding them through years of check, will possibly forgive—to the problem of establishing Sitka on the open moorland. Here the method just described is only applicable where the ground requires little or no draining. Where draining is required, foresters are now nearly all agreed that turf-planting is the best method. They are by no means agreed that the use of manure is necessary or desirable. On a fertile peat, or any soil containing a good proportion of mineral matter, manure certainly is unnecessary and in fact ineffective. On poor types of peat, the writer is convinced that manure is essential at the first planting, and that a second application in the form of a top dressing is often desirable, though perhaps not essential, if prolonged check occurs before the plantation has closed up. An example may be given.

An area, nearly flat and covered with very poor peat varying in depth from 1 to 6 feet, was turf planted with 2-year Sitka seedlings in 1909. Following the method evolved in the Belgian State Forests, each plant was given two handfuls of a compost composed of one part of basic slag to seven of sand. The

seedlings were very small and a good deal of beating up was done in 1910 with 2-year 1-year plants. All the plants got away well, and where the soil is least bad they are now over 20 feet high and past all danger. But the bulk of the plantation checked badly about four years after planting and remained stationary at about 4 feet till 1924, when the worst parts were top dressed with basic slag, two handfuls to each plant. The parts top-dressed have resumed a healthy growth and are closing up. The parts omitted from this top-dressing are now the shabbiest of the whole area and are to be top-dressed this year. The planting distance here was originally 3 feet. This is inconveniently close for Sitka and about half the plants were removed during the period of check and transferred to other sites. This is a point to which we will return in a moment. Meanwhile the reader will note that the removal of these plants helped to delay the formation of canopy.

Other examples of the use of manure are more spectacular. In one small Sitka plantation, made originally without manure in 1907, there is an average difference to-day of 25 feet in height between the trees in a section top-dressed in 1908 and the section omitted from this top-dressing. Many of the trees in the latter section are, twenty-four years after planting, only 3 to 4 feet high. Many are dead.

The writer will not presume to discuss the nature of the part played by these small doses of manure in the economy of Sitka spruce, but the tree certainly makes a wonderful response to this kind of encouragement. The experiments being made by the Forestry Commission should determine the minimum dose effective on various soils and the relative merits of rival manures and mixtures. The writer's experience tends to confirm the Belgian preference for basic slag, and for use at the time of planting the efficiency of the Belgian formula as given above. It is certainly very easy to overdo the dose—not in the sense of killing the plant, but in that of getting no value for your money. At Corrour in a top-dressing experiment made ten years ago, there is no difference to-day between the sections slagged at the rate of 30 cwt. per acre, and those which received only a third of that amount. For top dressing the slag can be used pure round the neck of the plant. To be effective in the coming spring, it should be applied before the end of November.

Turf-planted Sitka can be transplanted very easily, and even in hot summer weather there is practically no risk of failure. Checked plants, such as those mentioned above, are not of course so easy to move as plants from a turf nursery, where they have only been sitting two years and the root system has not extended beyond the turf. In the case of old-checked plants, even if they are not more than two or three feet high, the turf has practically disappeared and in lifting them with a ball such as a man can carry with one hand, important roots have to be severed. Yet, such is the power of recovery of this tree that there is an improvement the first year after moving, provided the plant is moved to better soil. The great objection to moving Norway spruce beyond the nursery stage is that the severing of roots results in pumped stems. As regards Sitka, the writer can only say that one of a group of plants moved

thirteen years ago has been felled and examined and there is no trace of decay. The tree was 35 feet high when felled. It had been in check ten years before moving. The vigour displayed by trees transferred to a good soil—even after 20 years of check—makes it difficult to believe that even this long period of stagnation permanently stunts its constitution or prevents it from attaining the full stature of which the new site admits.

A final word may be added on the question of seed origin. Seed from Alaska and from the Queen Charlotte Islands has given excellent results at Corrour. Much of the planting has been done with seed of unknown origin, and some races have proved unsuitable. One case may be cited. Two lots of plants raised at Pollok, Renfrewshire, in successive years from seed of unknown origin, were lined out at Corrour side by side in 1925 as 2 year 1-year plants and 2-year seedlings respectively. The older lot were twice badly frosted in the nursery. The younger escaped and were double the size of the older in 1927, when both lots were planted out, only a ride dividing them. The difference becomes more marked every year and in all probability the frost-tender batch will have to be replaced by hardier plants. Judging by the very poor results obtained at Corrour from seed of Norway spruce gathered within the Arctic Circle, it would be a mistake to assume that the types most suitable for trying positions in this country are those from high latitudes.

SITKA SPRUCE IN GREAT BRITAIN
ITS GROWTH, PRODUCTION AND THINNING

BY JAMES MACDONALD
(Research Officer (Scotland), Forestry Commission).

INTRODUCTION.

SITKA spruce is now used so extensively in forest operations in Great Britain that it is difficult to realize that we possess at the present time scarcely a single mature plantation of this species. Plantations up to 30 years of age are indeed numerous, plantations more than 30 years old, exceedingly few. Consequently, the writing of a paper of this kind is a difficult matter. On the one hand there is a real and urgent need for an accurate estimate of the possibilities of the species; on the other hand there is the scarcity of data on which such an estimate can be based. I propose, therefore, to examine the figures available and to endeavour as far as possible to collate and summarize the information in the hope that certain definite facts may emerge.

In 1928 the Forestry Commissioners published a bulletin on the 'Growth and Yield of Conifers in Great Britain'[1] in which a preliminary yield table for Sitka spruce was given. That table was based in all on 22 measurements of sample plots, both permanent and temporary, but since that time other 10 measurements have been made with the result that our information, though still scanty, is nevertheless a good deal fuller. This information has been derived from plantations established chiefly on the better soils. It is, naturally, the practice to give the first trials to exotics on good sites and it is only later, after they have proved themselves or have shown sufficient promise, that their use is extended to poorer ground. This has been so with Sitka spruce which is now largely employed in the afforestation of peat in various parts of Great Britain, but it is still uncertain how far the data which we now possess can be used as a guide to the possibilities of such sites, probably to a very limited extent, if at all. It is already certain that on the poorer peats, the height growth, at least in youth, follows an entirely different trend from that which is found on good soils.

MEASUREMENT DATA.

The table on pp. 102–3 gives details of the various Forestry Commission sample plots that have been measured. The figures are shown as per acre, and the girths, basal areas, and volumes are given in quarter girth measure. These are given by kind permission of the Forestry Commissioners.

[1] Forestry Commission, Bulletin No. 10. London 1928.

HEIGHT GROWTH.

The four quality classes which were drawn up for Sitka spruce in 1928 are sufficient to cover the range of height growth shown in the tables on pp. 102–3. The fastest growing of these plots (No. 41) is found to have a height growth rather better than quality class I (100 feet in 50 years), and the poorest a height growth corresponding to quality class IV (70 feet in 50 years). Of the 19 plots that have been measured, 3 are of quality class I, 6 of quality class II, 5 of quality class III, and 5 of quality class IV.

The plots of the first quality class comprise one plot which has been measured only once, and two permanent plots which have each been under management for about 10 years. The first (plot 582) is situated in Hampshire at an elevation of 400 feet on what was previously agricultural land and is growing in a loamy soil over chalk. It is fairly well sheltered and, at 19 years of age, had reached a height of 47 feet. Permanent plot 41 near Alcombe in Somerset is growing on what is said to have been old orchard ground in a well sheltered locality at an altitude of 300 feet above sea-level. The soil is a deep, fresh loam over the Devonian formation. This plot is remarkable for its height growth; at 13 years of age the mean height was 32½ feet, while at 22 years the mean height was 58½ feet. Thus, during 9 years, the mean height of the stand had increased by 26 feet—almost 3 feet per annum, and there is no sign of any slackening of the rate of growth.

In plot 57 at Dunach, near Oban, Argyll, which has been measured on two occasions, there are indications that the rapid early height growth is not being quite maintained. This plot is at an elevation of 200 feet and is fully sheltered. The soil is a good loam and the underlying rock is Porphyrite.

As regards the distribution of the 6 plots in quality class II, there is a marked concentration in the west of the country, 5 occurring in Dumfries-shire and 1 in Argyll. All are situated on loamy soils, but in plot 73 there is an admixture with peat, while in plot 416 the soil is described as a clay loam. Most of the plots are in more or less exposed situations, only plot 416 being moderately well sheltered.

The two permanent sample plots, Nos. 9 and 73, have each been measured on more than one occasion. These plots are situated at Drumlanrig, Dumfries-shire, where there is a remarkable series of plantations of Sitka spruce. In plot 9 the mean height has increased from 42½ feet at 21 years of age to 67 feet at 31 years, an annual increment of about 2½ feet, or rather more than is expected for the quality class. In plot 73 the mean height has increased from 45½ feet at 23 years of age to 54 feet at 27 years, an annual increase of about 2 feet. These plots are growing at an elevation of 600 to 650 feet with moderate to full exposure to the south-west and west. The geological formation is the Calciferous sandstone series.

Plot 416 which was measured at Glenbranter, Argyll, before it was felled, was of interest on account of its age, which was rather higher than that of most of the woods which have been measured. At 41 years of age its mean height was 77 feet, and there was no falling off in the height increment with

		Main Crop.								Thinnings.			Periodic Mean Annual Increment.	
Plot No.	*County.*	*Quality. Class.*	*Age.*	*Mean Height.*	*No. of Trees.*	*Mean ¼ Girth.*	*Basal Area.*	*Volume.*	*Form Factor.*	*No. of Trees.*	*Basal Area.*	*Volume.*	*Basal Area.*	*Volume.*
				ft.		in.	sq. ft.	cub. ft.			sq. ft.	cub. ft.	sq. ft.	cub. ft.
582	Hants	I	19	47	805	4¾	128	2590	0·431	150	13	225	—	—
P. 41	Somerset	I	13	32½	1645	3¼	125	1295	0·324	10	—	—	—	—
			16	42	980	4	115	1795	0·378	660	40	440	10	313
			18	47	905	4¾	140	2780	0·423	75	6	70	10·3	352
			22	58½	690	5⅝	151	3980	0·452	220	25	470	9	417
P. 57	Argyll	I–II	20	47	685	4¾	110	2010	0·396	125	3	8	—	—
			25	55½	475	6¼	130	3050	0·424	210	14	180	6·8	244
8	Dumfries	II	17	35	1030	4½	139	1860	0·382	—	—	—	—	—
232	Dumfries	II	20	41	535	6½	152	2340	0·375	—	—	—	—	—
233	Dumfries	II	20	39	795	5¼	153	2315	0·387	175	8	—	—	—
416	Argyll	II	41	77	465	8¾	248	7700	0·403	—	—	—	—	—
P. 69	Northumberland	III	16	30½	1610	3¼	115	1160	0·331	655	27	180	—	—
			21	37½	1265	4	138	2100	0·405	343	24	300	9·4	248
P. 70	Northumberland	III	15	25	2175	3	137	1045	0·305	295	4	—	—	—
			20	35½	1780	3⅞	184	2525	0·387	395	14	65	12·2	315

P. 9	Dumfries	II	21	42½	570	6¾	160	2570	0·378	10	1	8	—	—
			26	58	515	7½	198	4630	0·403	55	7	70	9·0	426
			31	67	480	8⅛	217	5910	0·407	35	8	155	5·4	287
P. 73	Dumfries	II	23	45½	870	5¼	174	3235	0·409	200	42	9	—	—
			27	54	725	6⅛	190	4265	0·416	145	12	150	7·0	295
P. 13	Kincardine	III	38	62	430	8¼	196	4780	0·393	55	11	210	—	—
			43	69½	370	9	201	5865	0·420	55	15	450	4·0	307
			47	78	370	9¼	221	6965	0·405	—	—	—	5·0	275
P. 14	Kincardine	III	38	64½	570	7	196	5280	0·418	90	11	240	—	—
			41	68	510	7½	199	5745	0·424	65	13	325	5·3	263
			44	71	505	7¾	206	6045	0·414	5	2	40	3·0	113
711	Hants	IV	24	32½	2010	3	125	1320	0·324	1165	17	—	—	—
10	Dumfries	IV	29	46	415	6	105	1920	0·396	—	—	—	—	—
146	Kincardine	IV	40	59	695	6¾	227	5740	0·428	75	7	130	—	—
P. 84	Argyll	IV	50	64	515	7⅜	196	5140	0·409	71	12	245	—	—
Alice Holt	Hants	III	21	32½	2113	3	131·4	1385	0·325	1165	22·6	—	—	—
Cockle Park	Northumberland	IV	30	43	1315	3¾	129	2500	0·450	680	35	340	—	—

increasing age. This is no doubt accounted for by the fairly good shelter which this plot enjoyed.

Quality class III includes 2 plots in Northumberland, 2 in Kincardineshire, and 1 in Hampshire, but no plots in the higher rainfall areas in the west. Two of the plots are on peat, 2 on peaty loam, and 1 on the heavy Gault clay; all are exposed to a greater or less degree with the exception of that at Alice Holt Forest, Hampshire, which is fully sheltered.

Into this quality class there fall the sample plots (Nos. 13 and 14) measured in the well-known plantations at Durris, Kincardineshire, which have now, unfortunately, been felled. These plantations were formed on peat up to 3 feet in depth overlying a boulder till on Felspathic Gneiss, and were planted in 1878 as a mixture of species which included Scots pine, European larch, Norway spruce, and Douglas fir. At the end the Sitka spruce formed almost a pure crop, only an occasional Douglas and Norway spruce surviving, generally in the lower canopy classes. These plots, therefore, give an indication of the rate of growth that can be expected on peat of a good type. There was the usual check after planting, because in 1884 it was reported that the plants were only then beginning to appear above the heather, but once the plantation became established the growth was excellent. During the last few years of its life plot 13 at least showed no sign of any marked falling off in height growth. This is shown by the following table which gives a summary of the measurements which were made of the leading shoots at the time the plot was felled. Measurements were taken of the length of the leading shoot for the last five years and recorded in inches to the nearest half-inch.

Stem Class.	*No. of trees.*	*Average length of leading shoot in inches during*				
		1929	*1928*	*1927*	*1926*	*1925.*
1 (Dominants)	85	16½	18	18½	19½	17½
2 (Co-dominants) . . .	49	15½	15	15½	15	14
3 (Sub-dominants) . .	8	10½	11½	12½	12½	13½

Thus, on peat in rather an exposed position the trees were still putting out, at almost 50 years of age, leading shoots of more than a foot in length.

The five plots in quality class IV are situated in widely separated parts of the country, one being in Hampshire, one in Northumberland, one in Dumfries-shire, one in Argyll, and one in Kincardineshire. One plot occurs on peat, one on a peaty loam, and the others on clay loams or clays.

Permanent sample plot 84 at Benmore, Argyll, is of interest on account of its age—50 years. It is situated approximately 700 feet above the level of the sea on a site rather badly exposed to the south and south-east. The soil is shallow and occurs in pockets among schistose boulders; it consists of a layer of fine peat 4 to 6 inches in thickness over a sandy loam which is slightly leached in the upper layers. At 50 years of age the mean height of this stand was

64 feet, which is just under the lower limit of quality class IV. When elevation, exposure, and soil are considered, this is quite a satisfactory rate of growth.

The plot at Cockle Park, Northumberland, the mean height of which at 30 years of age is only 43 feet, is characteristic of much of the growth on the hard boulder clays in the east of the country. The growth is irregular and during early life was exceedingly slow.

A plot measured at Cirencester, Gloucestershire, is remarkable for the poor growth which it exhibits. At 24 years of age it has attained a height of only 19½ feet and has not yet formed a canopy. The soil is a shallow loam with rock fragments on the limestone of the Great Oolite, and is doubtless too shallow and dries out too much in the summer for the best growth of Sitka spruce.

It has already been mentioned that one of the principal purposes for which Sitka spruce is now being employed is the afforestation of difficult peat. Most of the ground on which this peat occurs is relatively high-lying, and in many cases there is an additional adverse factor in the exposure which on such areas is frequently severe. Conditions are therefore entirely different from those which have given rise to the crops which are listed above. There is, unfortunately, little available information as to the rate of growth on such sites, but it is well known that the characteristic feature is the long check period immediately after planting. There is evidence here and there that, after the plants come out of check, height growth takes place at a moderately rapid rate. Nevertheless it seems scarcely likely that growth better than that of quality class IV will be reached, even on the best of the difficult peats, while on the worst types growth considerably poorer seems all that we have any reason at the moment to expect.

To sum up, quality class I Sitka spruce is likely to be found in limited areas where the conditions are specially favourable—on fairly rich, loamy soils where there is full shelter and a rainfall of at least 40 inches per annum.

Quality class II is likely to be the common rate of growth on good soils and in moderately well sheltered sites. It is also more likely to be found in the western half of Great Britain, as a reasonably high rainfall seems necessary.

Quality class III will be found to be the class occurring most frequently in areas of moderate to low rainfall on the better types of peat and on the boulder clays of the north-east, while quality class IV seems likely to be the general class in the low rainfall areas of the south-east of England, on soils which dry out in summer, and on good soils where elevation and exposure are important factors.

Sitka spruce withstands exposure better than the Norway, though less well than *Picea alba*. In exposed places, however, it suffers through the loss of its leading shoots which are frequently broken over; this is especially the case where the soil is favourable.

VOLUME PRODUCTION.

The British Yield Tables of 1928 gave provisional volume figures for the four quality classes of Sitka spruce up to the age of 50 years. These figures

showed that the production expected of this species is greater than that of any other species of conifer, and the most recent measurements of sample plots indicate that these estimates, high as they are, are likely to be realized. One or two of the plots indeed show remarkable production. Outstanding among these is plot 9 at Drumlanrig. The Sitka spruce in this plot were planted at a distance of 9 feet and, though the intervening spaces were afterwards filled with Norway spruce, this species was speedily suppressed with the result that the Sitka spruce have had ample room throughout. At 31 years of age the volume per acre was determined as 5,910 cubic feet, quarter girth, while the average volume of the individual stem was no less than 12·3 cubic feet. The increments, too, have been remarkable. Between the ages of 21 and 26 years the mean annual increment was 426 cubic feet, an increment which has only once in our experience been exceeded. This was in a sample plot of *Abies grandis* at Novar, Ross-shire. During the next five-year period, however, the increment was considerably less, due partly to the fact that a thinning was overdue.

A glimpse at the figures for the other permanent sample plots will suffice to show the high volume increments that may be expected from Sitka spruce. In these plots they are on the average in the neighbourhood of 300 cubic feet per annum, and only in one instance has the increment fallen below 200 cubic feet. This occurred in plot 14 at Durris where no real thinning had ever been carried out and where, in the end, thinning was impossible on account of the serious risk of wind-blow. In consequence, the trees were crowded, the crowns small and starved, and the crop generally at a standstill.

It should be added that the volume production of quality class IV Sitka spruce, the lowest quality class recorded among the plots measured, is as high up to 50 years at least as that of quality class I Norway spruce.

THINNING.

We have little experience of thinning in stands of Sitka spruce and, consequently, can offer only very general opinions as to their treatment. It might be argued that what is suitable for Norway spruce would be suitable for such a closely related species as the Sitka spruce, but this would be to overlook the silvicultural differences which exist between the species. These are considerable. In the first place, Norway spruce will tolerate a considerably greater amount of shade than Sitka spruce, and in a dense stand does not lose the foliage of its crown. Secondly, in stands of Norway spruce, the differences in height between the various stem classes are generally much more strongly marked than in similar stands of Sitka spruce. Thirdly, with Norway spruce, one frequently observes that the wood, if left untouched, will, as the saying is, 'thin itself'.

One finds here and there throughout the plantations that certain trees more vigorous than the others suppress their neighbours, and so reduce the density of the stocking without the aid of the forester. This does not occur so frequently with Sitka spruce which, if left untended, generally forms a dense,

drawn up crop in which all the stems are more or less of the same size. On account of these differences it is clear that treatment which may suffice for Norway spruce may not be at all suitable for the west American species. It has been pointed out, for example, that some of the finest crops of Norway spruce that have ever been grown in this country were never thinned at any time in their lives. This is quite true, and it is true also that those stands were apparently none the worse for that neglect, but it does not follow because a good crop of Norway spruce may be obtained without thinning, that Sitka spruce may be left to take its chance unthinned. On the contrary, if the crop is to be brought to its full development without loss of increment, systematic thinning is essential. It is for the forester on the spot to judge when the first thinning is necessary, as it is wrong to lay down fixed rules for such an operation. With the present-day planting distances, the first thinning need not be very heavy, but the succeeding thinnings should be as heavy as circumstances will allow. When there is any risk of wind damage, on shallow soils, or on peat, the opening up of the stand must be done with the greatest circumspection, but in sheltered places a really heavy thinning may be carried out with safety. If the first thinning has been delayed too long, it would be scarcely prudent to commence with a heavy thinning no matter how much the stand might be in need of such treatment. In many cases of this kind a reasonable density might be reached gradually by successive light thinnings, but in some even this might prove inadvisable. The forester, however, could then console himself with the reflection that even a poor crop standing upright is better than a good crop levelled by a winter gale.

A COMMERCIAL REAFFORESTATION PROJECT

BY ELLWOOD WILSON

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IN 1915 the Laurentide Paper Company Limited of Grand'Mere, Quebec, commenced what is believed to be the first definite commercial reafforestation scheme on the North American continent. Before describing it and the reasons which led to its adoption, a brief description of the forest situation in eastern Canada may be of interest.

The only Province which has, to any extent, alienated its public lands is Nova Scotia, where nearly all the land has been taken up by settlers. In New Brunswick, Quebec, and Ontario, only a very small portion of the total area has been settled and nearly 90 per cent. of the forests, as well as mineral and water-power resources, still remain in the hands of the Crown. Under regulations which are broadly similar, these lands are leased to the wood-using industries on payment of an annual rental or a minimum price for stumpage for the standing timber, and a further amount when it is cut. In Quebec, timber lands are leased or 'licensed' for a period of one year at an annual rental of $8.00 per square mile, plus the cost of fire protection which is handled by the licensees or 'limit-holders', through their co-operative protective associations. While the leases are for one year and can legally be cancelled for failure to pay the ground rent or fire protection, or for any infringement of the forest regulations, they are considered as the property of the licensee and can be sold, sub-let, willed, or pledged as security for loans with the banks.

At first the only requirement was that the licensee should protect them against fire, but with the growth of knowledge on the part of foresters, and the increasing forest consciousness of the public, the Quebec Government is requiring more and more. At first, the only restriction was that no timber could be cut under certain diameter limits, 2 feet from the ground: pine 10 inches, spruce 10 inches and fir 7 inches. This is still the law, but any one who wishes to cut under any other system can, by handing to the Government an estimate of the amount of timber to be cut, and a working plan, obtain permission to 'cut by exception'. An inventory, maps and working plans are now required, the working plans to be revised every ten years. Any one who will comply with all the requirements can now enter into a contract with the Government by which his holdings, if they are large enough, can be set aside as a permanent forest reserve for two rotations or 150 years. This is a forward-looking step, and the Quebec Government has been making steady progress in better forest legislation. As the licensees are fearful that new requirements

may raise the costs of operations, they have watched the Government closely and have a strong organization. Fortunately, the relations between the two are very intimate and friendly, and the foresters of the Government and the industries meet together and discuss ways and means for the better handling of the forests. The Government, realizing that the wood-using industries are second in importance, are always ready to listen to their needs and to adjust taxation so that, when the industries are prosperous, they contribute more to the expenses of Government, and when they are in difficulties, as at present, less.

About 1910, at the suggestion of Mr. George Chahoon, jr., one of the pioneers of the pulp and paper industry and a man of vision, the Government, under Sir Lomer Gouin, placed an embargo on the export of unmanufactured wood. This was the beginning of the rise of the paper industry in Canada which now leads the world.

In 1905 the writer commenced a survey of the forest resources of the Laurentide Company Limited of Grand'Mere, Quebec, covering 2,370 square miles, lying in the valley of the St. Maurice River, a tributary of the St. Lawrence, between latitudes 46° 30′ and 48° 30′ and longitudes 72° 30′ and 74° 30′. This survey showed that there was not enough wood to keep the mill in raw material indefinitely, that the soil in general was poor, that there were large areas of practically barren land owing to forest fires, where the natural reproduction was sparse, and other areas covered with aspen, white birch and jack pine, which would probably not yield coniferous crops for sixty to a hundred years. Moreover, the distances over which the logs had to be hauled and floated were long and were continually increasing, thus making operations more expensive and the losses in floating larger. All of these lands were leased from the Quebec Government at an annual rental of $8.00 per square mile per year, and the Company had to pay about $10.00 per square mile per annum for fire protection. Some way had to be found to provide timber for the future. Three methods presented themselves: to buy more Government lands, to buy and plant freehold lands, or to so change cutting methods that a second crop, heavier than the original, could be obtained earlier. The last was recommended, but met with such strenuous opposition from the logging department, due to the fear that logging costs would be greatly increased, that it was hardly considered. The first two courses were decided on and well stocked areas strategically located were purchased from time to time. Experiments in planting commenced in 1909. Some small areas of freehold land were already owned, and a scheme of systematic purchasing was commenced, having as its aim the acquisition of 200 square miles of land located within 10 miles of the mill. In 1912 or 1913 the Company decided to develop the water power which it owned at Grand'Mere and, in order to do this, it was necessary to purchase the lands which would be flooded. These consisted of lots which had been granted to settlers by the Government, having a frontage of about 9 chains on the river and an average depth of about 63 chains. As only a portion of each lot was to be flooded, the remainder could be planted. The tract

originally chosen for purchase had been opened to settlement by the Government some forty years before and almost all of the forest had been cut and burnt in clearing it. The soil is a poor sandy loam with numerous swamp areas, unfit for agriculture, and should never have been settled. The land had run out, nearly every farm was mortgaged, the people were poor and discouraged, and were gradually drifting into the then prosperous mill towns where work was plentiful.

The basic idea was to build up a forest for the supply of pulpwood to the mill from 1947 on, amounting to 75,000 cords, or half its annual requirements. The reasons for this were that planted forests would be fully stocked and earning money steadily, whereas the mature timber on licensed lands would be steadily deteriorating. The cut and burnt-over areas would take a long time to grow another crop, and one could not be sure how long it would take to start or what the final crop would be, either in species or stocking. From rate-of-growth studies it seemed probable that cut-over lands would take 60 years, and burnt-over sections 80–100 years, before they could be cut again. The area required would be much smaller, with large savings in fire protection, ground rents, and administration charges. There would be no stumpage dues to pay when the trees were cut. The time lost in waiting for natural reproduction would be saved. The species would be those best adapted to paper-making, and there would be less decayed wood. The time required to float the wood to the mill, now averaging nearly two years, would be saved, and two seasons' growth added. The sinkage loss, said to average 4 per cent. the first year, and 17 per cent. the second, would be avoided. The interest on the money spent in cutting the wood for two years in the rivers and one year in the storage piles would be saved. There would be no need of measuring the wood in the forest. There would be no dams to build, and no money need be spent on clearing out the small streams and bad places in the rivers. No camps would have to be built in the woods, and no provisions carried over for a year to feed the men. No roads would have to be built. The woods work would be directly under the eye of the General Manager, to almost the same extent as the mill operations, and the whole plant would be self-sustained and self-contained. In case of lessened demand for paper and the necessary curtailment of operation, the trees would continue to grow and there would not be the huge piles of rotting wood which now dot the Quebec landscape.

It may be noted in passing that in 1914 or 1915 one of the large paper companies of Canada, with more optimism than judgement, bought up large tracts of woodlands with an eye to expansion, and not being able to carry the interest charges, ground rents, and fire protection, had to go into liquidation and fell into foreign hands, losing large sums of money for the public. Other companies made the same mistake, but not with the same disastrous results, although the difficulties which the industry is now experiencing are partly attributable to this cause.

There was also the social side to be considered. Labour in the woods is becoming less skilled and harder to get and the men—and the Government—

demand better living conditions. The men do not like to leave their families alone all winter, and the women object to caring for the cattle and doing the hard work through the long winters. The planting and nursery work does not interfere seriously with farm work and the men can live at home. As the cutting could be continued the year round, they would be assured of steady work, planting and harvesting.

Before deciding on a final policy, the writer paid visits to a number of nurseries and plantations in Canada and the United States, and in 1911–12 visited Norway, Sweden, France, Switzerland, and Germany, to study nursery and planting methods. The ease with which natural regeneration is obtained in eastern Canada and the north-eastern part of the United States, and the difficulty in Europe was very marked. Experiments, on a small scale, were carried out with different species in a small nursery; seed-spotting was tried. Efforts were made to study the ecology of the native species, their rates of growth, diseases and insect enemies.

The general attitude of the industry toward any efforts to increase the productivity of the forest by better cutting methods or by planting was more or less hostile. Even if planting were profitable, it was not feasible; it might be successful in Europe, but our conditions were different. It was felt that there was perhaps enough wood to last forever, or that Nature would provide for the future, the general opinion being that a new crop could be harvested every 15 or 20 years. The Government owned the lands, let them look out for themselves. In one instance, the head of one of the companies proposed to the industry that no forester of any company should be allowed to write or publish anything about reafforestation for fear the Government might make it compulsory for the licensees.

In order to demonstrate what could be done, a few small plantations of Scots, white, and jack pines were made, as these species grow rapidly and would give the quickest results and make a show. People hardly believed that trees could be grown.

The first step in the programme of land purchase was to map the prospective areas so that a thorough knowledge of their suitability and value could be obtained. A small section was surveyed and the use of aerial photography having been demonstrated by the writer, the whole region in the neighbourhood of the mill was photographed. The individual holdings were examined and classified and a basic price fixed for each kind of land, swamp, brush land, timber, and cleared land. Whenever there was a tendency to raise prices, the buying was moved to another section which prevented inflation.

It was decided to develop a nursery of our own. A level tract of land with a railway siding, about 6 miles from Grand'Mere, was chosen. The soil was a light sandy loam, old farm land pretty well run out, and required very little grading, and no drainage. The elevation above sea-level was 500 feet. A range of hills to the north and east offered a certain amount of protection from wind. After 16 years of operation it has proved all that could be desired.

After grading, the land received a heavy dressing of well-rotted stable manure and lime, and the spots where the sandy subsoil had been exposed were given a heavy dressing of decomposed peat and an extra application of manure. A water-supply system was installed, the supply being drawn from a small lake on the property and pumped up into a tank.

It was decided that Norway spruce would be the easiest species to handle in the nursery and would give the best results. At first it was thought that it would be cheaper and better to purchase stock for planting. From 1909 to 1912 spruce stock was purchased from the United States and Scots pine from the Quebec Government Nursery. The latter turned out to be from a cheap German source of seed and the trees are of very bad form. One shipment of spruce stock was not true to name and practically every variety was included in it. The stock from the United States, due to the earlier season, was often too far advanced to be in good planting condition.

From the very first the growth was slow, although the mortality was low. In talking with foresters with planting experience, they said that the slow growth was attributable to shock of transplanting, but we were not satisfied with this explanation and felt that the source of seed, the way the stock had been grown, and methods of planting were responsible. In order to study this matter we began pulling up trees in the plantations that were growing slowly and we found that, invariably, those that had been planted too deep, or that had the roots bent or bunched together, were doing poorly or dying slowly. As we had opportunity to study older material we found in some instances that, after three or four years, sometimes after ten years, the trees formed new roots, near the surface of the ground, and commenced to grow vigorously.

In 1917, in order to study the question of rates of growth, influence of light, effect of thinnings, &c., sample plots were established in the plantations and in the forest. A station in the forest, the first forest experiment station in Canada, was laid out, buildings erected, and sample plots located. The work was done in co-operation with the Commission of Conservation under Dr. C. D. Howe and Mr. Clyde Leavitt. When this Commission was abolished the work was taken over by the Forestry Branch of the Dominion Government and the plots have been re-measured every five years. The first experiments in girdling hardwoods were made here. Different methods of thinning were tried to find the effect on growth and regeneration.

Very soon after the work was started it became apparent that there was a great lack of information about the chemistry and biology of forest soils, mycology and entomology. There were many studies of rates of growth, there were stand and yield tables, but practically nothing helpful was known about ecology of the forest, what the mutual influences of trees in various associations were, why the same species on one site grew well and on another, which was precisely similar as to aspect, elevation and climate, and where the soil and soil-moisture conditions appeared to be similar, gave poor results. Investigation of these problems was impossible for a commercial company, with forestry just

beginning to be heard of. There were no Government agencies in Canada to undertake the work, and very little is being done to-day, but the work at the Yale Forest School and at the Boyce-Thompson Institute in New York was fundamental and helpful.

Almost all of our forests are mixtures of conifers and hardwoods, and it seemed a pity not to take both species in one logging operation. Under the logging methods in vogue, the cutting of the conifers leaves the hardwoods with less competition, and gradually large areas are turned over to hardwood growth. Experiments were carried out in the making of paper from hardwood on a commercial scale and it was found that up to 15 to 20 per cent. of the ground wood pulp could be made from hardwoods. Also, the fuel value of different species of hardwood was carefully determined to see if it could replace coal to some extent. The idea of all these trials being to find some way by which the hardwoods could be reduced and the amount of conifers in our forests increased.

As there were stands of all ages on portions of the area acquired for planting, experiments in different methods of thinning were carried out. The effect of pruning was studied and experiments in planting on soils enriched with different amounts of stable manure were carried out.

Not being satisfied with the seed obtained from dealers, we began to collect our own: white spruce, red, white, and jack pine. This was collected from the general neighbourhood of the plantations, from the best and most vigorous trees, and a seed extracting plant was built. The general method is to bring the cones to the drying shed as soon as they are collected; those of white spruce heat very quickly and are soon damaged, so must not be left long in sacks or piles. Here they are put into wire-bottomed trays about 3 inches deep, which are placed in tiers in a well ventilated room, with sufficient heat to give ventilation by drawing the air in from outside at the floor level and letting it out through the roof. The cones are allowed to air dry, turning them occasionally to prevent heating, until the men are free from other work. They are then fed into revolving drums in a heated chamber; in the case of white spruce, the temperature is kept as low as possible and with no species is the heat allowed to rise above 120° F. It has been found that the germination percentage is highest when very little heat is used. The furnaces for drying cones are entirely heated with empty cones. For some years the seed used in the nursery did not have the wings removed, but later we decided to clean the seed. After it is extracted, it passes over a cotton belt about 3 feet wide, which slowly revolves in the opposite direction to that in which the seed is falling; this removes some of the dirt and needles; it falls off this belt in front of an electric fan which blows the lighter seeds away and lets the heaviest and the next heaviest drop into compartments. The seed is then moistened and passes through a series of brushes which take off the wings, then it is finally cleaned in a centrifugal machine developed by the Brown Corporation of Berlin, New Hampshire. The seed is stored in glass jars. A small amount of quick-lime is placed in the mouth of each jar and the corks are sealed with paraffin

wax. These are stored in a well ventilated underground concrete chamber where the temperature varies very little from 56° F.

The seed beds are laid out nearly east and west, 3 feet 8 inches wide, and any convenient length. We generally use 60 feet × 3 feet 8 inches. Paths 18 inches to 2 feet wide separate them. For a number of years the beds were slightly raised above the general level of the nursery, made slightly convex, but no boards were put around them. The last few years we have gone back to boards, as there was some loss of plants from the breaking down of the edges of the beds. Ordinary lath screens are used. These are made by machinery and can be rolled up easily to one end of the beds, as the season advances, and the trees need hardening off. Seeding is done either in the spring or fall, as is most convenient. Seed sown in October germinates more evenly and earlier than does that sown in the spring.

The early germination gives a longer growing season and enables the seed caps, which attract the birds, to fall off before they come north in the spring. As there is more moisture in the ground, less watering is required, lowering the cost. Before sowing, the beds are sprinkled and the seed broadcasted at the rate of 22 to 24 ounces per bed or 1 pound to 160 square feet. Sowing is done, as far as possible, when there is no wind, to avoid uneven sowing and loss of seed. The seed is covered by sifting soil over the seed from a sieve the width of the bed. The beds are covered with *Sphagnum* moss which allows the surface water to penetrate and prevents the beds thawing out too quickly in the spring. This is taken off as the seeds begin to germinate. We often have severe thunderstorms in late June and during July, and the heavy downpours coat the seedlings with earth. To prevent this, we have strips of heavy canvas which can be rapidly unrolled over the shade frames. As little watering as possible is done, and the trees are gradually hardened off by rolling back the screens a little longer each day. Little care is necessary during the second summer. If the weather is exceptionally dry, the seed beds are watered always at night. They are kept free from weeds. In the fall, just as the ground is freezing up, the seed beds are thoroughly sprayed with a lime sulphur mixture of 75 per cent. strength.

For a long time we found that the plants along the edges of the beds grew better than those in the centre which were often quite yellow in colour. We thought that this was due to the soil being too acid and used heavy dressings of lime. This did not correct the trouble, which we finally decided was due to lack of nitrogen. By using a light dressing of dried blood this has been corrected, and the seedlings show a better growth and much healthier colour. After the transplants are lifted, the soil receives a heavy dressing of well rotted stable manure, about 15 tons per acre, and every other year about 1,000 pounds per acre of powdered limestone. A soiling crop is then planted; we usually use buckwheat. This is rolled just after flowering and then ploughed under.

In the earlier days of the nursery, the transplanting or lining-out was done by hand, using the 'Yale' transplant boards. The furrows were made by hand.

For several years we worked on a plough which would make a furrow, with one straight side, in our light soil. Due to the efforts of Messrs. R. W. Lyons and G. G. Cozens, we were finally successful and the whole method of transplanting was changed, materially speeding up the work and lowering the cost. The trees are lifted by being loosened with a wide round-tined fork. The boys then take a bunch of trees in each hand and shake off the earth from the roots, placing the trees in pails of water; these are taken to canvas shelters where they are threaded into the 'Yale' boards by girls and carried to the furrows by boys. A special type of board has been developed, seven feet long. The board is shod with a strip of aluminium in which the notches are cut. These hold the trees better, keep cleaner, and much increase the life of the board. The shelters for the girls who do the threading are placed on either side of the area to be planted. The plough, drawn by a small tractor, opens a furrow up the centre of the area, turns, and comes down the other way alongside of the furrow already made. It continues to make the circuit of the area, up one side and down the other, until the whole is planted. The boys with the transplant boards follow the plough and a man back-fills the earth against the roots of the plants with the back of a rake. Another man follows to see that the roots are properly covered and firms the earth with his feet. A crew will easily transplant 250,000 trees per day of 9 hours. Fall transplanting is not done due to the loss through heaving.

There is practically no mortality in transplanting. The plants are left in the transplant beds for 2 years, weeds being kept down by cultivators. Experiments have been carried out in using 2-year seedlings and 2 plus 1 transplants. The former can only be used where the land is clean, i.e. has been ploughed the previous year, or is covered with a light sod. The latter have not a sufficiently developed root system to be satisfactory, and the cost of another year in the nursery is very low. We need a strong plant with a well developed root system to get the best results on our heavy sod areas or in planting in hardwood brush.

Planting out is done in the spring and fall. Beginning as soon as the frost is out of the ground, the work is carried on till the buds begin to open. In the fall, planting begins about the first of September and is carried on till the middle of October. This gives the plants a chance to get well set before the frost comes and causes heaving. The trees are lifted and packed in boxes with layers of *Sphagnum* moss and taken by motor lorry, wagons, or boats, to the planting site. A special short-handled shovel is used, something like a grocer's sugar scoop, but not so deep. It is pointed and the edges are kept sharp. The shovel man will make holes for three planters. In sod areas he first cuts off the sod by a rapid stroke, then takes out enough earth to leave a hole deep enough to take the roots without their being bent. The planters are served by boys carrying galvanized pails of transplants always with some muddy water in the bottom, so that the plants never get a chance to dry out. The planters are supervised by a foreman who sees that the plants are not set any deeper than they were in the transplant lines, and that the roots are well spread out

and neither bent or bunched together. This is most important. It is very poor economy to spend 4 years in raising transplants and then to plant them carelessly in order to save a few cents per thousand. The whole secret of success is careful planting. Sometimes the effect of bad planting does not show up for several years, and then the trees suddenly begin to grow poorly and gradually die. The results of our work have proved this and the mortality in our plantations is almost negligible, amounting to not more than 5 per cent.

Almost from the beginning we naturally began to have trouble with insects; the white pine weevil (*Pissodes strobi*, Peck) attacked the Norway spruce and Scots pine, and there was no information as to the best methods of handling it. Experiments were undertaken of cutting off the weeviled shoots and putting them in screened boxes where the parasites might develop and escape. This treatment, combined with the cutting out of all badly weeviled old white pines in the neighbourhood, soon brought results.

Trouble started in the nursery with the snow fungus (*Phacidium* blight) and there was absolutely nothing in the forestry literature about it. Dr. Faull, then at the University of Toronto, kindly consented to undertake a study and within a year had isolated the fungus, grown it on culture media, learned its life history, and devised a spray which is an absolute preventive. He also carried out an important study on the fungi which attack living conifers, the manner in which they attack trees and the resulting injuries to the wood. He also gave us some information about the fungi which attack the wood in the piles. This study was followed by one on the utilization of such infected wood, in co-operation with Price Brothers & Company and the United States Forest Products Laboratories. Wood infected with each of the common rots was made into paper, the pulp analysed, and the paper tested. It was found that, except where the wood was completely disintegrated, it could be used for paper with good results, and much wood that had previously been wasted was salvaged.

There has also been an infestation on all the spruces of spruce gall aphid, but without damage. On poor soils a few of the weaker trees have been infected with *Chermes*. The damage in no case has been serious enough to kill the trees.

The results of the work have been thoroughly satisfactory. Seventeen square miles have been planted with 21,000,000 trees and the whole aspect of the district has been changed. More than fifty families have been moved from unproductive farms and have installed themselves in the villages where the living conditions and school opportunities are better. The population is trained in nursery, planting, thinning, and fire protection work. The growth of the trees has been greater than was expected. The Scots pine, planted in 1915–16–17, has had its first thinning and has yielded a cord per acre of material large enough for pulpwood, up to 7 inches in diameter breast high. Our oldest Norway spruce plantation, made in 1914, shows an average height to the beginning of this year's leader of 17–18 feet, an average diameter

6 inches above the ground of 3·67 inches and a volume of 995·5 cubic feet per acre. There is the following stand per acre:

Total, 1,320 *trees.*

Diam. 6 in. from ground.	*No. of trees.*
1·0–1·9 in.	110
1·9–2·9 „	190
2·9–3·9 „	510
3·9–4·9 „	370
4·9–5·9 „	110
5·9–6·9 „	10
6·9–7·9 „	10

The height growth has been gradually increasing, and during the last two seasons the average has been over 2 feet. Leaders 4 feet long on Norway spruce and 3 feet in white spruce are numerous.

Accurate costs have been kept by our accounting department since 1917, when we began to plant on a large scale. As the costs of establishing plantations have been paid out of revenue each year and treated as an operating expense, practically as a replacement charge, compound interest has not been used, only simple interest at 6 per cent. per annum. The costs are shown in the following table compared with two actual logging operations of two different companies. The comparison is favourable to the planted timber.

Cost per acre.	£	*s.*	*d.*
Land	1	15	2
General Preparation	0	12	6
Ditching	0	0	2
Trees	1	19	8
Planting	2	6	3
Office and Supervision	0	12	2
Fence Maintenance	0	0	7
Road Maintenance	0	0	2
Taxes	0	0	9
Fire Protection	0	0	3
	7	7	8

Cost per acre.

Carried forward to the end of the rotation of 35 years.

	£	*s.*	*d.*
Land	5	9	0
General Preparation	1	15	7
Ditching	0	0	5
Trees	6	3	1
Planting	7	15	8
Office and Supervision	1	17	7
Fence Maintenance	0	1	10
Road Maintenance	0	5	9
Taxes	1	8	6
Fire Protection	0	10	8
	£25	8	1

It will be noticed that in the above costs there is no item for beating up the plantations. Since we have improved our planting methods this has not been necessary, and no plantations made since 1920 have required this work.

The estimated yield, which is based on measurements of natural and planted stands, is 2,700 cubic feet per acre in 35 years, or 77 cubic feet per acre per annum. The total cost of cutting and delivering to the mill, on the basis of known delivery costs, is estimated at 19*s.* 6*d.* per cord of 90 cubic feet. Adding the cost of growing, 16*s.* 11*d.*, the total delivered cost will be 36*s.* 5*d.* This compares favourably with the average cost of wood delivered at the mill from licensed lands of 46*s.* 1*d.*, but to this must be added 7*s.* 4*d.*, being interest for the floating time, a three and one-third per cent. loss in floating, one year's interest for the time in storage, and 1 per cent. deterioration; also the Government stumpage charge of 5*s.* 6*d.*, which brings the cost of the wood ready to go into the mill to 58*s.* 11*d.* per cord, a difference of 22*s.* 6*d.* per cord in favour of the planted forest.

As spruce is a native of this country and has been growing on the same soils for centuries, soil exhaustion is not greatly feared, but in order to avoid this, after the trees are established and have reached a height of 6 to 8 feet, natural growth of *Betula lutea*, *B. populifolia*, *Salix*, *Populus tremuloides*, and on the better soils, *B. lutea* and *Acer spicatum* and *A. Pennsylvanicum*, &c., which are very plentiful, is allowed. Some plantations of mixed spruce and red pine, mixed spruce and Scots pine have been established, but these mixtures are not considered satisfactory.

Once in three or four years we have a late frost in June and the leaders of Norway spruce in small low-lying areas, 'frost pockets', are killed back. Usually the interval between frosts enables the trees to pass the frost line. As a matter of routine, however, white spruce is planted in these situations. It is probable that as the Norway spruce becomes acclimatized, its buds will not open so early and it will become hardy.

So far, only very small areas have had to be cleaned, as most of the planting has been on abandoned farms. Where areas have been clean cut the hardwood sprouts and seedlings grow faster than spruce, and have to be cut when the spruce is about 3 feet high. Thereafter it can hold its own. Some underplanting has been done under birch and aspen brush and here, when the conifers are established, the brush is girdled with a light chain saw. A man will do as much as two acres per day. The cost of cleaning is about 6*s.* per acre.

Two look-out towers control the planted areas for fire detection and watchmen are kept in these whenever there is danger of fire. The fire losses since the beginning of the work have been about six acres. These have all been in the spring in grass areas. The principal danger in the past has been the railways, but in recent years they have co-operated fully, and we no longer look on them as a source of danger. The two worst fires occurred in 1930; one was started by a burning house and, although we had it surrounded by men, sparks from the roof flew over their heads and fired the grass in which it spread rapidly, due to very high wind. The other was begun by a man hauling dry half-rotted

wood who dropped the ashes from his pipe on it. Wood and wagon caught fire and ignited the grass along the roadside. As the plantations get older the trees along the edges are pruned and the hardwood shrubs grow up and kill the grass, materially reducing the fire hazard.

This work has demonstrated that a paper company can grow its own raw material, and with the constantly increasing distances over which wood from natural forests may be transported, with increasing costs and losses, it seems sound economically to invest money in growing pulpwood, rather than to spend it in holding huge areas of deteriorating stands, burnt and cut-over areas which will take nearly a century to re-stock incompletely.

A good deal of effort has been expended in educating the men in the work and to get and keep them interested in it. Each year the foremen have been taken to nurseries and plantations in Canada and the United States, to show them how others do the work, and to broaden their outlook. During the last two years a school has been carried on in the evenings to which the men came voluntarily and in their own time. The results have been really extraordinary, and we have as fine a body of employees trained in nursery and plantation work as can be found anywhere. This has been one of the greatest factors in our success.

The opposition to any improvement in cutting methods or silvicultural practice has come in the past from the woodland managers, who have been, until recently, men without any technical training. The situation has changed materially, and now the woodland managers of nearly all the large companies are technically trained men, mostly forestry graduates with a few engineers. For the most part they have fought shy of any planting operations, and have given little thought or investigation to its advantages through a desire to keep down costs, and taking it for granted that timber could not be grown economically. They have hesitated to advise their managements to tie up money in planting, but have not hesitated to advise the purchase of standing timber, sometimes very disadvantageously located. The far-seeing and really big men in the industry have been ahead of the foresters in thinking about better silviculture and the improvement of their holdings, and it is not too rash to prophesy that the pulp and paper industry in Canada will turn to cutting methods which will insure a better crop, and will realize that it pays better to have smaller holdings near their mills rather than really vast areas of low productive capacity.

NOTES ON THE BIOLOGY OF THE LARGE ELM BARK-BEETLE, SCOLYTUS DESTRUCTOR OL.

BY RONALD C. FISHER

WITH PLATE V

INTRODUCTION.

WITHIN recent years it has been shown that the elm bark-beetle, *Scolytus destructor* Ol., is associated with the occurrence of Dutch elm disease which has recently spread throughout the southern counties of England, and has caused the death of many trees. It is suspected that this insect may play an important part in facilitating the spread of the fungus believed to be the cause of the disease. For this reason an account of the life-cycle and habits of the elm bark-beetle in this country may be of interest and of use for determining more precisely the exact role played by the insect in relation to this disease of elm trees.

The work which is described in the following paper forms part[1] of a study of the structure and biology of the genus *Scolytus* (order Coleoptera, Family Scolytidae), as represented in Britain, made by the writer from 1921–4 whilst holding a Ministry of Agriculture and Fisheries Research scholarship. The work was carried out in the entomological laboratory of the Forestry Commission, at that time located at the Royal Botanic Gardens, Kew, and under the supervision of Professor J. W. Munro, then entomologist to the Commission. Experimental work and field observations were conducted in Kew Gardens, Richmond Park, and in other localities in the London district.

HISTORICAL.

The large elm bark-beetle, *Scolytus destructor* Ol., together with the small elm bark-beetle, *S. multistriatus* Marsh, may be found abundantly in felled elm logs in the south of England. *S. destructor* in particular has long been associated with injury to elm trees in the London district, and various accounts of its depredations in that area have been published, but information on the biology of the insect is scanty and incomplete. The work of Chapman (1) forms the basis of our knowledge of the biology of the genus *Scolytus* in Britain. Prior to Chapman, Denson (2) gives an account of damage to elms near Cambridge, but little attention is paid to the habits and biology of the insect.

Continental literature on the large elm bark-beetle is also scanty. Guérin-Méneville (5 and 6) has observed the habits of the beetle in France, but while

[1] An account of the Relation of the Elm Bark-beetles to their Host Trees was published by the writer in *Forestry*, vol. ii (1928).

he describes in detail the method of pairing, and discusses the relation of the health of a tree to its liability to attack by *S. destructor*, no information is given regarding its life-history, the duration of its stages, or the number of generations per annum. Schoevers (10) gives a short account of the life-cycle in Holland, and records interesting observations on the feeding habits of the adult beetles.

Whilst *S. destructor* has been more or less neglected by workers in entomology —probably because of its comparative unimportance from a forestry point of view—there is an extensive literature, British, Canadian, American and European on *S. pruni* and *S. rugulosus*, the two members of the genus of importance to the fruit grower. The bionomics and control of the birch bark-beetle, *S. ratzeburgi*, have frequently been investigated in Russia, Sweden and Germany [Trédl (13)]. The biology and forest importance of the small elm bark-beetle, *S. multistriatus*, have been discussed by Macdougall (8), but otherwise this species, and also *S. intricatus*, have received little attention.

LIFE-HISTORY AND HABITS.

A study of *S. destructor* necessarily differs considerably from that of the pine dwelling bark-beetles. In the case of the latter, if one felled pine wood be found there is abundant opportunity for observing the habits of the species studied on many trees, logs or stumps within the one locality. In the genus *Scolytus*, on the other hand, so far as the two elm-dwelling species are concerned, observations in the field must usually be confined to isolated trees felled here and there in a number of districts. There is not the same opportunity of studying the beetles on one extensive area.

First Emergence of Beetles in the Year. Elm-bark collected from logs in the end of April 1922 contained larvae fully grown and about to pupate: field observations were not made prior to 15 May, when work was begun at Kew. The first adults emerged in the laboratory on 18 May from bark brought in from the field. On 1 June adults were found in numbers in the field flying around logs from which they had emerged. In 1923 when observations were made throughout winter, spring and summer, the first adults were found in pupal beds in the field on 29 April, and the first beetle was found feeding on young elm twigs on 4 May. In the laboratory the first beetles which had developed from eggs laid in August 1922 emerged on 2 May 1923. In the south of England therefore, adults which have overwintered as larvae may be expected to emerge from the beginning of May onwards, the majority issuing towards the end of May and in the beginning of June.

In the bark-beetles generally the proportion of the sexes seems to vary even in one particular species. According to Escherich (3), only in a few instances is there any accurate information on this matter. He states that in *S. destructor* the proportion of the sexes is 30 to 40 males to one female. The writer has not observed such a high proportion of males, although it was definitely noted that they exceeded the females considerably. The following figures were obtained

from emergence records made from bark collected in the field in early summer 1924.

Date.	*Males.*	*Females.*
22 May .	4	1
26 May .	7	3
29 May .	10	11
31 May .	9	2
2 June .	20	10
4 June .	36	12
5 June .	18	9
Totals .	104	48

i.e. approximately 2 males to 1 female.

Feeding Habits of S. destructor. It has been shown by several workers on the families Curculionidae and Scolytidae that the adult beetles immediately after transformation from the pupal stage are sexually immature, and that feeding is necessary in order to develop the reproductive organs. The nature and place of this feeding vary in different species of bark-beetles. Some species tunnel for this purpose in the leading shoots of trees, for example *Myelophilus* spp.; others feed beneath the bark prior to emerging, for example *Cryphalus* spp. A knowledge of the feeding habits of the genus *Scolytus* as represented throughout the world is yet incomplete. Swaine (12) includes the genus among those genera of the Scolytidae which leave the parent tree and cut food tunnels in the bark of other trees. Spessivtseff (11) in Sweden, confirming work by Wichmann (14) on the feeding of young adults of *S. laevis*, *S. pruni* and *S. pygmaeus*, has shown that in the case of *S. laevis*, which he has studied in detail, feeding is indispensable after the beetles first emerge. He found that the actual type of feeding took many forms, the beetle boring into young green twigs at nodes, at the base of buds, forming short tunnels beneath the bark or even feeding upon leaf stalks and slender green twigs. Spessivtseff adds that the feeding period of *S. laevis* is of short duration, lasting in warm and sunny weather only four or five days. He urges the necessity of a study of the feeding habits of all species of *Scolytus*.

Schoevers (10) in Holland briefly states that *S. destructor* cuts feeding tunnels on branches, beneath buds, of elm trees. The feeding habits in England of the genus *Scolytus* are quite unknown. Examination of the reproductive organs of newly emerged females of *S. destructor* shows them to be immature, the egg tubes being small, without any trace of developing eggs, and the terminal chambers empty and undeveloped. Feeding of some description is apparently necessary before such females can lay eggs. During summer 1922 several preliminary experiments were carried out to ascertain whether Spessivtseff's observations on *S. laevis* were also true of *S. destructor*. Numbers of newly emerged beetles were confined in a cage with freshly cut elm twigs. The beetles gnawed away the bark, particularly at the nodes (Fig. 1), and an indication was obtained of the type of feeding to be looked for in the field. On

dissection of several females, after four to seven days feeding, the egg-tubes contained developing eggs and several fully developed eggs.

In spring 1923 a suitable locality was found in which the feeding habits of *S. destructor* could be observed. Beneath several large elm trees lay many blown and cut branches containing numbers of larvae of the two elm bark-beetles. In the immediate neighbourhood healthy young coppice elm was growing, some 10–15 feet high. In the axils of the twigs of these trees signs of old *Scolytus* feeding tunnels were observed partly healed over by callus. On 4 May the first adults of the year were found feeding on these young trees when two beetles, males, were seen beginning to tunnel in the axil of a small twig. From that date onwards throughout spring and summer, beetles, males and females, were found feeding on fresh young twigs on coppice elm trees and on the branches, within range of observation, of old standing trees.

The feeding takes the form most typically of a semi-circular tunnel (Fig. 1), cut beneath the bark generally beneath the nodes on slender branches or twigs and even on the main stem of young trees. In some cases no tunnel is formed but the bark is gnawed away in irregular patches (Fig. 1). Leaf stalks were not eaten, nor were tunnels excavated at the base of buds as Spessivtseff observed in *S. laevis*. Several beetles may feed successively at the same spot, and the resulting tunnel or patch of gnawed bark increases correspondingly in size. An experiment was conducted in the field to investigate further the feeding habits of the elm bark-beetles. On 4 May a young growing elm tree, 10 feet in height, was entirely enclosed in a cage of wooden frame-work covered with muslin. In the cage were placed a quantity of bark containing larvae and pupae of *S. destructor*, and a fresh unattacked elm log. By 6 May three beetles had begun to feed in the axils of the young twigs, and from that date onwards until the end of June, when the experiment was closed, beetles were found feeding. Hardly a node on the whole tree escaped attack. Beetles were not found boring into the elm log in the cage until 11 June, fully a month after the first adult was observed feeding on the tree. Cold unseasonable weather prevailed during this time, and it is probable that these conditions brought about a prolongation of the feeding period. Furthermore, the experiment was conducted in the shade of overhanging large elm trees. From 11 July onwards many entrance holes were noted in the log and egg tunnels were found.

While feeding of some description is essential for the development of the reproductive organs of *S. destructor*, observations have shown that this feeding does not always take place upon young twigs. In a series of experiments where beetles were placed in the field in cages containing elm logs and freshly cut young branches and twigs, it was found that, whilst some beetles fed upon the twigs, others at once began to burrow into the logs, apparently thus obtaining the nourishment necessary for the development of their reproductive organs. On examining the tunnels made by these beetles several weeks later, it was noticed that if eggs were present the first centimetre or centimetre and a half of the tunnel did not contain eggs. This portion thus represented that part

of the tunnel cut before the egg tubes were mature. Tunnels made by immature beetles may serve only as feeding tunnels, in which case these may be abandoned and new tunnels made for egg-laying. Feeding tunnels of this type in the bark of logs vary from 1 to 2 centimetres in length. In the field numerous feeding tunnels have also been located in the thick bark of the main stem of standing trees and in the swollen buttress-like growths so often found at the base of elm stems. Dissection of beetles taken from such tunnels showed that they were immature.

An attempt was made in spring 1924 to obtain by experiment further information on the duration of the feeding period. Small gauze cylinders were placed over twigs on standing trees and newly emerged beetles introduced. Beetles were dissected at intervals of 4, 8, 10, and 13 days and it was found that the ovaries showed little sign of development. Traces of developing eggs were present but no fully developed eggs were seen. In some instances, even after twenty days, the reproductive organs were still immature, although evidence of feeding on twigs was quite distinct. In all cases where, after feeding periods varying from a few days to three weeks, the egg-tubes still showed little sign of becoming fully developed, nematode worms were found in large numbers in the body cavity of the beetles and in the posterior parts of the reproductive organs, e.g. the bursa copulatrix, and the alimentary canal. Where few eel worms were present it was noted that after a feeding period of approximately eight days the egg-tubes were well developed although not yet fully mature. It was thus evident that numbers of nematodes caused a delay in the ripening of the ovaries. The above observations confirm the statement by Escherich (3) to the effect that parasitic nematodes effectively delay the ripening of the reproductive organs and thus cause a prolongation of the feeding period. A rcent account of infestation of elm bark-beetles by a nematode, *Parasitylenchus scolyti* n.sp. has been published by Oldham (9).

From the results of the above experiments it is apparent that it is impossible to state any fixed feeding period as necessary for the development of the female reproductive organs of *Scolytus destructor* prior to egg-laying. The period varies in individuals, depending not only on conditions of temperature and sunlight, but also upon the presence of parasitic nematodes within the beetles, and occupies from approximately one week up to three weeks or even longer.

Pairing. The sexes mate soon after emergence and pairing may take place within feeding tunnels on young twigs or within the entrance to egg galleries on elm logs. It was noticed, and confirmed by experiment, that one male paired with several females. This repeated pairing was observed soon after emergence of beetles and when the tunnels had just been commenced by the females. Pairing was not observed either in the field or in experimental work after egg-laying had been in progress for a short time: repeated pairing throughout the summer does not therefore appear necessary for the continued egg-laying of a female. When the beetles were commencing their egg-tunnels for the first time after emergence, males were found in numbers running over the logs and pairing with females at the mouths of the tunnels. Later on,

FIG. 1. Elm twigs showing feeding tunnels (A) made by immature adults of *S. destructor* Ol.

FIG. 2. Tunnels of *S. destructor* Ol. and *S. multistriatus* Marsh. on surface of elm log after removal of bark. Note exit holes (A) from pupal cells in wood.

PLATE V

however, after the tunnels had been in process of excavation for some time and while the females were still present, males were few and seldom seen. These observations confirm Chapman's statement to the effect that the males are present for a short time only.

The Egg-tunnel. In *S. destructor* the male does not appear to play any part in the cutting of the egg-tunnel. The female beetle cuts her tunnel preferably in the thick, coarse bark of the main stem or larger branches of elms. Sometimes the species is found along with *S. multistriatus* in the smooth bark of smaller branches, 2 or 3 inches in diameter. Chapman records that he did not find the larger elm bark-beetle in branches less that 8 inches in diameter. On the smaller branches the entrance holes are easily visible, but where the bark is thick and rugged it is difficult to find the entrance to a tunnel, although its position may be indicated by the presence of reddish brown dust pushed out by the beetle as she excavates her tunnel. In its normal habitat, in thick bark, the female bores at first straight in, or at a steep angle, until she reaches the surface of the sapwood. The typical gallery is then cut in a longitudinal direction, along the axis of the log. Although the general rule is for the tunnels to follow this direction, there are often many irregularities to be found, for example, mother-tunnels running at an angle across the log or curving to some extent around it. More variation in direction is found on small branches than on the large limbs or main stems where the majority of the egg-tunnels are typically longitudinal in direction. The female cuts her egg-tunnel between the innermost layers of the bark and the surface of the sapwood, cutting distinctly into the sap so that the pattern of the tunnel is well defined and visible on removal of the bark (Fig. 2). The entrance burrow of *S. multistriatus* has been described by Macdougall (8) as resembling the head of a golf club. The same description applies to the first part of the egg-tunnel of *S. destructor*. This portion is slightly broader than, and at a slight angle to, the rest of the tunnel. In Chapman's words, 'there is often a trace of a diverticulum near the entrance of the burrow'. This part of the tunnel may be regarded as a suggestion of the pairing chamber found in the brood galleries of some of the bark beetles. In *Scolytus* the male remains, during pairing, on the surface of the log, with the abdomen projecting into this portion of the tunnel occupied by the female.

One female may cut more than one egg-tunnel and this, apparently without a further pairing. On many occasions it was noticed that a female which had been excavating an egg-tunnel suddenly abandoned it and began a new egg-tunnel on the same log. For example, in one instance five egg tunnels were cut by three females after removal of all males from the cage. Apparently, a tunnel is not abandoned because a further pairing is required before egg-laying can continue. In another case five females made as many as eleven entrance holes in a log. This number, however, includes feeding tunnels, trial burrows and egg-tunnels. Egg-tunnels have been found as short as 0·75 cm. in length and the longest measured was 9 cm.: the average of a series was slightly over 4 cm. The breadth of the mother gallery varies from 3–4 cm. So far as seen, ventilating

burrows which occur at regular intervals along the mother galleries of various bark-beetles, do not occur in the tunnels of *S. destructor*. Such ventilating burrows are a feature of the mother galleries of the birch bark-beetle, *S. ratzeburghi*.

Oviposition. The eggs are laid, as by many other bark-beetles, each in a small niche cut in the side of the tunnel and near its floor, and are carefully packed in position by 'bore dust' which also lines the sides and part of the roof of the tunnel. The neat, regular packing along each side of the egg-tunnel is well seen if the roof of such a gallery is carefully removed. Although the actual deposition of an egg was not observed, the condition of the numerous tunnels examined during egg-laying indicated that the female cuts a part of the tunnel, gnaws out the egg niches and then returns to deposit an egg in each, finally packing it in position with the dust produced by her tunnelling. Some of this dust passes through the alimentary canal of the beetle, while some is merely pushed behind the insect by vigorous scraping and pushing with its legs. Having thus laid eggs in the part excavated, the female then proceeds to gnaw a further portion of her tunnel and the above process is repeated.

The number of eggs in a tunnel varies with its length; the shorter tunnels contain twenty to thirty eggs, but the number in a tunnel of average length amounts to from eighty to a hundred. Tunnels were found with as many as 150 eggs, and Chapman has counted even more than 160 eggs per burrow.

On emerging, the young larvae at once proceed to tunnel at right angles to the mother gallery. Since the egg-tunnel is situated partly in the inner layers of bark and partly on the surface of the sapwood, and since the eggs are laid low down on the sides of the tunnel, the newly emerged larvae groove the surface of the sapwood as well as the bark. The normal direction of the larval tunnels gives a characteristic appearance to the brood galleries. Larvae, emerging from eggs laid at the extremities of the tunnel, burrow in a longitudinal direction. Larvae emerging from eggs situated towards the centre of the mother gallery, burrow for a longer distance more or less at right angles to the egg-tunnel, but gradually work round to a longitudinal direction. The pattern thus produced by all the larvae associated with one brood tunnel assumes the characteristic form associated with *S. destructor*. Although at first the larvae tunnel between the bark and wood surface, as they grow, in many cases they burrow towards the surface of the bark, and when fully developed excavate their pupal chambers just beneath the surface. Others, especially in thin-barked logs bore into the sapwood for pupation, excavating pupal chambers in the surface of the wood, or even in some instances, cutting quite an appreciable tunnel into the sapwood and there forming their pupal chambers. In this case the adults, when ready for emerging escape from the wood through the old larval tunnels (Fig. 2). When larvae pupate near the surface of the bark the young adults eat their way out, leaving exit holes. The length of the larval tunnels varies from 6 to 9 centimetres; the maximum tunnel measured was 10 centimetres in length.

Duration of Stages in the Life-cycle. The duration of the egg stage was found to vary from 11 to 14 days.

The first pupa in experiments carried out in 1922 in the laboratory was obtained on 18 July, 48 days after the parent beetles had been placed on a log. In spring 1923 the first pupa was obtained on 14 July, from a larva emerging from an egg laid by a beetle introduced to the cage on 24 May, i.e. after a period of 51 days, which corresponds closely with the period recorded the previous year. The duration of the larval stage of this brood averaged 6 weeks, but in some cases this stage of development is prolonged over a period of several months when the pupa does not appear until the spring of the following year. The effect of sunlight on the rate of development of larvae was clearly shown in an experiment conducted in a shaded locality among young coppice elm beneath large trees. On a log in which beetles, after a prolonged feeding period, were commencing to tunnel on 12 June no larvae were yet fully grown by 30 July when the experiment was suspended.

The pupal stage is of comparatively short duration, lasting from about 10 to 13 days.

Emergence of New Brood. In the experimental work the first adults derived from eggs laid in the last week of May and in the beginning of June emerged between 24 and 28 July, after a period from egg to adult of 8–9 weeks. If these beetles were allowed to remain in the cage along with the same log as that in which they had passed their egg, larval and pupal stages, they commenced to bore into the log and cut egg-tunnels. Although most of the larvae emerging from eggs laid in June were full grown and pupated during July and August, others did not pupate until the following spring but passed the winter as partly grown larvae. Chapman (1) states that he obtained a brood of beetles emerging in August, but he was unable to ascertain what happened to them as he obtained no evidence of oviposition nor of hibernation.

When beetles of the new brood emerged in July and August they were transferred to new cages with fresh logs, and there eggs were laid from which larvae emerged and fed, passing the winter one-half or two-thirds grown. Pupation took place the following spring, and the adult beetles of the new brood emerged in April and May. The emergence of broods in the field corresponded closely to the results obtained in the experiments. The first adult from eggs laid in spring issued from control logs between 20 and 26 July. It is of interest to note that in the field on 30 July large numbers of dead beetles were found on the control logs which had been under observation throughout winter, spring and autumn. Some of these beetles had apparently just commenced to cut their burrows whilst others were lying in crevices in the bark. They were probably newly emerged adults of brood B 1 (see diagram, p. 129), killed by an unexpected drop in temperature, following a period of heat. Unfortunately, the beetles had been dead for too long a period for dissection to confirm their age. Whilst many adults emerge and are to be found in flight during May and June, and, again from the end of July and during August when beetles of the new brood emerge, yet it cannot be stated that

'swarming' is confined to these months. Owing to the marked overlapping of broods and generations beetles may be found in flight right throughout the summer from May until September.

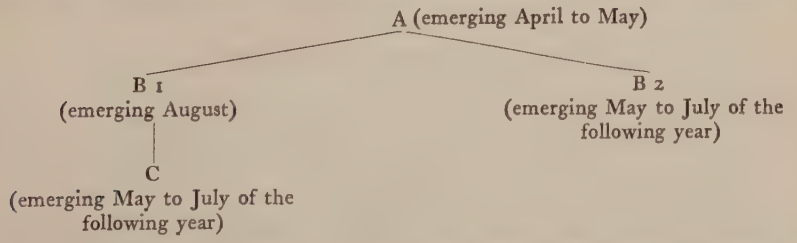
Subsequent Behaviour of Parent Brood. During the series of experiments conducted in 1923, the results of which were confirmed in 1924, it was noted that of beetles commencing egg-laying in the middle of May, the majority were found dead, either in their tunnels or on the floor of the cages, by the middle of July, after a period of 6 to 8 weeks. The few beetles still alive, after this period were all females. In many species of bark beetles, after egg-laying has been in progress for some time the parents do not die but leave their breeding grounds and proceed to feeding grounds there to renew feeding prior to a second egg-laying. This does not, however, seem to be the case in *S. destructor*. Dissections of beetles taken from tunnels have shown developing eggs present in the ovaries, even although no fully mature eggs were to be found—yet egg-laying was proved already to have taken place by the presence at the base of the egg tubes of the yellow bodies, consisting of discarded and degenerate egg follicle, known as corpora lutea. Furthermore, during July, more than two months after the first emergence of adults in the year, a thorough examination in the field showed very few beetles feeding on young elm twigs. Dissection of numbers of these beetles showed by the absence of *corpora lutea*, that they had not yet laid eggs but were newly emerged beetles feeding for the development of their reproductive organs. Numbers of beetles were found during July feeding on the thick bark of the main stem of a standing tree. Dissection again showed that these beetles were immature adults late in emerging.

These observations would seem to indicate that egg-laying is carried on continuously throughout the summer, the females deriving the necessary nutriment during the excavation of egg-tunnels. The actual duration of egg-laying of a single female would appear to extend from 5 to 10 weeks, but the egg-laying period of beetles of brood A (see diagram) extends from May to August and possibly longer. This is because beetles of brood A continue to emerge during the whole of this period. The result is that adults of this brood are still egg-laying, and in some cases only commencing egg-laying at the same time as the children of their brothers and sisters which have emerged earlier in the year. The experimental work has shown that, in captivity, in no case did adults overwinter. All beetles used in the 1922 work were found dead when the cages were examined in October of that year. On 11 December, 1922, however, two female beetles were found alive but very inactive, and with every appearance of hibernating, in short tunnels, on the main stem of standing trees, 15 to 20 feet high which had previously been attacked by *S. destructor*. Possibly other beetles were present, but the position of the trees situated in a public thoroughfare made further examination impossible without defacing the stem. This is the only occasion upon which adults were found so late in the year: it suggests that several individuals may be capable of hibernating in short tunnels on young stems or in crevices in the bark of older trees. A careful search was made in all likely places, on felled logs, on twigs, standing trees, on

newly felled trees in an effort to find further evidence of beetles hibernating. No other instance was observed. One is, therefore, inclined to believe that the presence of the two beetles taken in December, 1922, is exceptional and may be accounted for by the mild, open weather experienced during the autumn of that year. Further information on this question is required.

Number of Broods and Generations in One Year. This has long proved a vexed question in bark-beetle biology. The researches of Hennings (7), have, however, shown that the rate of development of bark-beetles depends upon conditions of temperature and humidity. It is therefore not always possible to state definitely the number of broods and generations in any given year, assigning regular times and periods to the different stages. In any one year the life-history may vary according to the climatic conditions prevailing throughout the period. Hennings, in a series of experiments with *Ips typographus*, found that at a temperature of 24° centigrade and relative humidity of 55 per cent. the period of development from egg to mature adult (i.e. after completion of feeding) occupied 26 days. At a temperature of 14° centigrade and relative humidity of 55 per cent. this period was increased to 100 days. He found that optimum conditions of temperature and moisture existed for the rapid development of a bark-beetle from egg to adult, and concluded that in general within limits, the higher the temperature and the lower the humidity the more rapid the rate of development.

The life-history of *S. destructor* as followed from April 1922 till August 1923 is summarized below. Throughout this period observations in the field and in the laboratory showed that the development of this bark-beetle is also considerably affected by climatic conditions. For the sake of convenience let the beginning of the year's life-cycle be counted from the time of egg-laying of the first beetles to emerge in spring. Those beetles, brood A (see diagram), which continue to emerge throughout the spring and summer, May to July, lay eggs during this period. A considerable number of the larvae emerging from these eggs become full grown, pupate and give rise to a brood of beetles (B1) which issue towards the end of July and during August. The remaining larvae do not become full grown until the following April and May when in due course a new brood of beetles (B2) emerges. The beetles of this brood lay eggs in August and the larvae emerging from these do not mature until the following spring when they in turn give rise to the adults of another brood (C). The adults of this brood therefore emerge at the same time of year as those of brood B2. The cycle may conveniently be represented in diagramatic form


A (emerging April to May)
B 1
(emerging August)
B 2
(emerging May to July of the following year)
C
(emerging May to July of the following year)

Summarizing the relation of the broods within one year, i.e. from the

hatching of eggs laid by adults emerging in April to May until the corresponding time the following year, there would appear to be three broods of beetles—B1, B2, and C. Broods B1 and B2, related as brothers and sisters, are children of brood A, while brood C are children of B1 and grandchildren of A. Consequently, while there are three broods in the year there are only two generations, B1 the first generation, and C the second generation.

So far as observations have shown, beetles of brood A die after egg-laying for a period of two to three months, and do not proceed to feeding grounds for recuperation prior to a renewal of egg-laying. Beetles of this brood which, however, have been late in emerging may be found egg-laying at the same time as the children of other beetles of this brood which issued earlier in the year. Marked overlapping of broods thus occurs, the explanation of which has been shown by Hennings to be due to a large extent, to variations in conditions of temperature and humidity. Where logs were situated in localities shaded from the sun the rate of development of the broods of *S. destructor* was found to be prolonged. In consequence of this overlapping of broods and generations it is difficult to describe the life-cycle strictly as annual since the life-history of the species must be modified according to the conditions prevailing in the locality in which the insect is present. Although in general the life-cycle of *S. destructor* is as described above, variations will also occur from year to year in the duration of the stages and in the times of emergence of the adult beetles.

ACKNOWLEDGEMENTS.

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AN INSTANCE OF 'DAMPING-OFF' RETARDED BY THE USE OF BASIC SLAG

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INTRODUCTION.

IN the spring of 1930 an experiment was laid down in the Imperial Forestry Institute nursery at Kennington, Oxford, to test the effect of manures applied both before and after sowing on the out-turn of 1-year seedlings of Scots pine, Corsican pine, *Pinus contorta*, European larch, and Sitka spruce.

The experiment was carried out by the Research Branch of the Forestry Commission, and the article is presented by permission of the Forestry Commissioners. The principal object of the experiment was to produce a suitable type of 1-year seedling vigorous enough to be planted direct into the forest. This article will not discuss the result of the experiment, but place on record observations, mainly of mycological interest, on the beneficial effect of basic slag, when the whole experiment was subjected to a severe attack by 'damping-off' fungi.

SOIL CONDITIONS AND PREVIOUS TREATMENT.

The area on which the experiment was laid down consists of a sandy loam, resting on sand derived from Calcareous grit. The soil tends to cake, particularly after rain.

The area was originally meadow land, converted by ploughing during 1925–6. It was under coniferous transplants during 1927, soiling crops (mustard) during 1928, and was laid down as seed-beds (oak) during 1929.

LAYOUT OF EXPERIMENT.

The layout consisted of 5 seed beds, 100 feet long by 3 feet wide. Nine treatments were under study, there being 5 replications of each treatment, arranged on Randomised Blocks. The unit area for each treatment was a 9-foot length of seed bed 3 feet wide. Buffer strips occurred between each unit, and boards were inserted to prevent wash from adjoining plots. Each unit plot consisted of 4 drills, 1 inch in width, spaced 4 inches apart, for each of the 5 indicating species. The density of sowing for each species was as follows:

Sitka spruce	1	gramme	per drill or	1 lb. to	454 square feet.
Pinus contorta	1½	grammes	,,	,,	304 ,,
Scots pine	1½	,,	,,	,,	304 ,,
Corsican pine	2	,,	,,	,,	227 ,,
European larch	2	,,	,,	,,	227 ,,

The density of sowing was purposely heavy to ensure an even distribution when the crop was subsequently thinned. Of the nine treatments studied only four

are selected for special consideration in the present article in addition to the control. These treatments were as follows:

1. Control, seed-beds prepared in the ordinary way with no manurial application.
2. Broad-leaved humus, spread over the bed to a depth of 3 inches, and worked into the surface layers to a depth of 3 inches.
3. Farmyard manure applied as in 2.
4. Basic slag worked into the top 3 inches of bed, applied at the rate of 2 lb. 6 oz. per square yard or 5·1 tons per acre.
5. Sulphate of potash applied at the rate of 4 oz. per square yard, and worked into surface layers as in 4, at the rate of 10·8 cwt. per acre.

DETAILS OF TREATMENTS.

On 15 April the area was cultivated by Rototiller, to a depth of roughly 9 inches. On this date the seed-beds were slightly raised and suitably firmed by treading. The broad-leaved humus was well decomposed and was obtained from an open Oak wood. It was riddled and, on application, was worked into the surface layers of the bed by forking and raking. The Farmyard manure, well decomposed, was applied in the same way. The basic slag was first scattered evenly over the surface of the bed and then worked into the soil by raking. The sulphate of potash was applied in the same way. In each of the above applications, the bed was suitably firmed before being finally raked. On 16 April drills were marked out to a depth of $\frac{1}{8}$ inch. by drill roller. On the same day sowing was commenced, and completed on 22 April. This operation was interrupted from time to time by rain. The seed was covered with coarse sand, the drills being lightly pressed after covering. Previous to sowing, the seed was soaked for twenty-four hours in cold water. Before sowing, each unit was watered with a 1 per cent. copper sulphate solution at the rate of 1 gallon per 27 square feet. The object of this was to kill weed seed. Moist conditions prevailed from the time of sowing until germination was complete. The dates when germination commenced were as follows: Corsican pine, 7 May; Scots pine, 10 May; European larch, 13 May; *Pinus Contorta*, 15 May; Sitka spruce, 20 May.

'Damping-off'[1] was first observed on 29 May, being most pronounced in the Corsican pine sowings, while other species were affected, but to a less noticeable extent. On examination it was observed, except in the case of Corsican pine, that at the stage of development where the plant falls over, the withering of the stem, caused by 'damping-off', was at a much lower level on the stem than is usually the case. Instead of occurring above the soil level, it was found generally below the root collar. In order to check the spread of the fungus, Cheshunt compound was applied on above date at the rate of 1 gallon to 27 square feet. Owing to the high water content of the soil, a ready absorption was not obtained. This treatment proved ineffective and a general spread of the fungi to all species and treatments with the exception of basic slag plots

[1] The fungus concerned was not studied, but Mr. W. R. Day identified it as a *Fusarium* sp.

followed. The attack became most severe about 2 June, when a further application of Cheshunt compound was made, the same amount being applied as in the case of the first application. On above date an assessment was made, to determine the effect, if any, which the various manurial treatments might have had on the spread of the fungus. At this period it was again observed that the characteristic withering of the stem was very low, especially in the case of Sitka spruce. It was frequently observed that for this species the radicle was dead to just below the root collar.

The severity of the attack became less apparent after 2 June, when a dry spell occurred, and finally ceased round about 19 June.

The following Table gives the mean percentage loss from 'damping-off' fungi in the different species and all treatments:

	Average percentage of deaths in				
Treatment.	*Corsican pine.*	P. contorta.	*Scots pine.*	*Sitka spruce.*	*European larch.*
Control . .	70·6	76·5	71·2	92·4	57·8
Broadleaved Humus.	77·6	82·4	80·6	92·8	63·0
Farmyard Manure.	77·2	76·0	80·8	91·0	66·6
Control . .	78·8	75·6	81·4	94·6	66·8
„ . .	79·0	84·2	79·4	88·2	76·8
„ . .	72·4	73·0	78·2	86·0	64·6
Basic Slag . .	21·6	15·2	16·8	9·8	15·8
Sulphate of Potash.	45·6	37·2	53·0	72·6	26·0
Sulphate of potash. +Ammonium phosphate.	61·4	68·4	72·4	88·2	55·6
Standard Error[1] .	8·18	5·91	9·13	6·9	7·55
Difference required to give a 20 to 1 probability of significance.[1]	24·5	17·7	27·4	20·7	22·7

DISCUSSION.

The above table clearly shows the losses which can be caused by 'damping-off', and indicates the importance of these fungi, especially where coniferous species are concerned. Factors favouring the development of the fungi appear to be numerous, and in some instances these same conditions are also ideal for germination. From present observations it was found that a high relative humidity favoured the spread, and that with the occurrence of a dry spell the

[1] For method of calculation and use of standard errors see Forestry Commission Bulletin No. 11.

intensity of the attack diminished. The following figures, which are the relative humidity as weekly means, show this point more clearly.

Period endings.	*Relative Humidity.* per cent.	
13 May	94·7	
20 May	94·7	
27 May	94·2	Attack became serious.
3 June	93·8	
10 June	92·5	
17 June	77·5	
24 June	71·7	About this date attack ceased.
1 July	59·0	

Observations were also made on adjacent beds of Scots pine of the same origin, but where germination took place twelve days earlier than in the experiment under discussion. In this case losses due to 'damping-off' were practically nil and a full crop was obtained, which suggests that the size of seedlings at the time when the fungi is active is an important factor.

Factors responsible for the retarding effect which basic slag had on the spread of the fungus unfortunately are not available, as a soil analysis was not made.

It is, however, of interest to note that despite the heavy application of slag, the type of seedling produced was well balanced with well ripened shoot and little sign of forcing. This type of seedling to all appearances is one that should not be affected by change of environment. Sulphate of potash also had a beneficial effect, although much less marked than basic slag.

SUMMARY.

Effective methods of control of 'damping-off' from the practical point of view have presented great difficulty. The application of Cheshunt compound in solution to large scale work has, in the writer's experience, proved ineffective. A ready absorption is, as a rule, impossible owing to the high water content of the soil which is usually prevalent when the attack is most severe.

Tilth conditions are of known importance, especially in the case of sensitive species, and should receive due consideration. Surface caking hinders germination, and it has been observed that seedlings succumb to the fungi in such cases before appearing above ground. On the evidence presented, basic slag is to be recommended as a check to the damage for the type of conditions under consideration, although the conclusions are based on one year's observations only. Whether smaller applications would have the same beneficial effect has yet to be determined.

On the other hand, improved nursery technique is suggested as being a factor which may greatly reduce losses. For it appears that the older the seedling the less susceptible does it become to attack. In this connexion, earlier sowings for some species are suggested.

WOOD PRESERVATION: AN INTRODUCTION

BY R. S. PEARSON, C.I.E.

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THIS article is a brief introduction to the series which will follow on the subject of Wood Preservation.

The popular idea is that investigations conducted to ascertain the best methods of preserving wood are limited to devising ways and means of introducing some powerful antiseptic into the timber, the efficiency of which has been proved by durability and service tests. Were we to remain content with this state of affairs, progress would be slow, and research, except along these lines, hardly necessary. The whole subject is a far more complex one.

To arrive at the most economic methods by which wood can be protected, when taking into consideration the many different uses to which it is put, it is necessary to study the mode of growth of the fungi which attack it. It is equally necessary to study the chemical composition of the wood in relation to the food-stuff required by the fungi, the chemical changes which take place in wood after attack, and to consider, from a chemical standpoint, suitable antiseptics with which to protect the timber. The entomologist has a similar task: he has to study the life-history of the insects which destroy wood; to study the biology of the insects, and in co-operation with the chemist and mycologist determine the necessary nutrition required by each species of insect. Another aspect of the problem is the necessity of determining the most economic and thorough method of introducing an antiseptic into timber. This largely depends on the species to be dealt with, the solution selected for use, and the degree of treatment necessary to protect the timber, taking into consideration the conditions of service to which it will be subjected. It will be readily realized that this entails much labour and expense, as the number of species of wood employed is great, their relative power of absorbing solutions vary widely, and the number of uses to which treated timber is put is very considerable. Investigation of this order could not be carried out to the best advantage without the assistance of a detailed knowledge of the anatomical structure of the wood, and here the wood technologist can render invaluable assistance to the wood preservation officer. Not only can he predict beforehand which timbers are likely to be refractory to treatment, but it is his duty to investigate the way in which an antiseptic actually penetrates the fibre.

From what I have said, it follows that the problem of the preservation of wood has to be approached from several different angles, namely from a chemical aspect, that of the entomologist and mycologist, that of the engineer who has to introduce the antiseptic into the timber, that of the wood technologist, and finally from an economic aspect.

The method in general use to protect wood from decay is to treat it with a recognized antiseptic; the other method and one which is as yet in little use, is to alter the conditions in the wood, either physically or chemically, and so render it unsuitable for the development of fungi or to attack by insects. The papers which follow deal in some detail with these questions, and will, amongst other points, touch on the necessity of a more intimate knowledge of the relation between decaying organisms and the chemical composition of the wood and its derivatives; the need of full biological knowledge of wood-destroying beetles; the necessity of studying the growth of fungi and the preparation of type cultures for identification; the relative value of different antiseptics to protect wood against the many different species of fungi and insects which attack it; and the need of studying the way in which antiseptics penetrate timber and the various processes devised to introduce such solutions into the timber.

THE TOXICITY OF PRESERVATIVES AGAINST WOOD-DESTROYING FUNGI

BY K. ST. G. CARTWRIGHT

(Forest Products Research Laboratory)

INTRODUCTION.

DETERIORATION of wood can be brought about through both mechanical and chemical agencies, the former including wearing due to traffic and both animal and insect attack. Chemical damage may be either direct, as may occur in factories employing chemical processes, or indirect, due to fungal attack, though no sharp line of demarcation can be drawn between these two.

With direct mechanical damage we are not concerned in this paper, and with damage caused by insects Dr. Fisher will deal; suffice it to say that evidence is accumulating to show that micro-organisms are often involved in such damage. Direct chemical damage can be combated either by protecting the wood or by using timbers resistant to chemical attack.

Now I come to the damage caused by fungi, which is in reality as much a chemical action as that due directly to the action of chemicals. The principal agencies of decay in timber are insects and fungi, and it is probable that in this country at least 80 per cent. of the damage is due to fungi, and even in cases where severe insect attack has occurred it has been generally found on investigation that the attack has followed on that of fungus. (It has been stated that in the United States of America the annual loss in wood products due to fungi reaches a grand total of 4 billion cubic feet.)

Fungi occurring on wood are numerous, some attacking the living tree, some confining their activities to the sapwood, some to the heartwood, whilst the majority can attack both. They may in some cases be specific to the wood or confine themselves to one class of timber, others, again, appear to be equally at home on both soft and hard woods. Time will not allow of my describing the many fungi that attack wood, but they may be classified broadly into:

1. Degrades,
2. Destroyers,

the former confining their activities principally to the sapwood, feeding on the cell contents, although many of them are capable of penetrating the wood elements, the latter boring through the wood elements freely, and by their chemical action on the cell-wall substance destroying the wood. They are usually divided into two main groups, though this division is one purely of convenience and is not strictly accurate, as will be pointed out in a later paper dealing with the chemistry of the problem.

1. *The brown rots*—these principally attack the cellulose, leaving a dark residue of lignin.

2. *The white rots*—which attack the lignin leaving white pockets or patches of a substance that looks like cellulose.

Before the advent of the compound microscope little advance could be made, and the study of wood decay has followed closely in the footsteps of advance in optical science.

Whilst investigations into the biology and chemical action of fungi are of paramount importance, and it is through the results of such work that the ideal preservative treatment will be discovered, it is imperative that the best use should be made of those at present available, the former being the long distance approach and the latter of more immediate application. It is with this second close range approach that I intend to deal with in the main, though I hope to be able to indicate the lines on which fundamental long range research is likely to develop; this aspect of the subject, however, will be further developed by Mr. Campbell.

First of all, what is required of a preservative? An ideal preservative should fulfil the following requisites:

1. Toxic to the fungi attacking the timber and must not damage or discolour it. (I shall qualify this statement later.)
2. Must readily penetrate the wood.
3. Should be as permanent as possible, that is, it should not be easily leached out, volatilize, or easily decompose.
4. Should not be dangerous to handle by those employing it.
5. For many situations it is also essential that it should be odourless and not increase the fire risk.
6. Must be able to be produced at an economic price.

Preservative substances, proprietary and otherwise, are legion in number; some of them very efficient, others useless. Therefore, in order to separate the sheep from the goats, tests of these materials, in the first place under controlled conditions in the laboratory, and secondly, on a full scale under service conditions, are essential.

The laboratory tests are in the nature of preliminary heats in order to eliminate those preservatives which may prove to be useless; it must be stressed that such small scale tests can never replace the service tests which in the final instance are the only reliable ones for the practical man. Preservatives fall into three main classes:

1. The tar oil group, which includes creosote, wood tars, &c.
2. Salts, e.g. zinc chloride and the fluorides, and others, such as mercuric chloride and arsenic salts.
3. Mixtures of 1 and 2.

In addition there are some volatile substances, the vapour given off being the toxic element. The advantages of the tar group are: high toxic value, fairly permanent, comparatively low cost; and the disadvantages: smell, fire risk, paint cannot be applied directly to the treated wood, stain plaster, &c.

The advantages of the water soluble salts are: high toxic value, little or no

smell, good penetration in steeping, paint can be applied directly to the treated wood; and the disadvantages: easily leached out, some may attack glass and nails, &c., higher cost of some of them.

Water insoluble salts overcome some of these disadvantages, but have the initial difficulty of the treatment. Undoubtedly such a preservative, if it can be got into the wood and laid down inside the wood as a water insoluble salt, would combine the advantages of both groups and get over many of the disadvantages, and such a process has been patented in America, the weak acids of the fungus bringing into solution the toxic salt zinc meta-arsenite; others using solution agents which afterwards evaporate, have been tried out, but so far the ideal preservative working on these lines has yet to be discovered. It can be seen, therefore, that, until the ideal preservative has been discovered, which combines the advantages of both without their disadvantages, their properties naturally make creosote and the tar oil group most suitable for outdoor use owing to their greater permanency than salts, whereas salts are usually more suited to indoor use where they are not directly exposed to leaching out by rain, as wood thus treated can afterwards be coated with paint. In addition, the use of tar oils in houses or food stores is often put out of court owing to their strong odour.

With the various types of salts I have not the time to deal here and will pass on quickly, giving a general account of the methods of testing the relative toxicity of preservatives.

Laboratory tests fall into two main divisions: firstly, those carried out on a medium other than wood, and secondly, those employing wood either in the form of wood blocks, sawdust, or wood pulp, the last named falling in between the two classes. Each method has its advantages and disadvantages, and a great amount of controversy has arisen regarding the merits and demerits of tests on artificial media as compared with those on wood.

Most of the work on the testing of wood preservatives has been carried out in Germany or America, the former adhering mainly to the wood-block test, the latter to the agar one.

HISTORICAL.

It is only within the last thirty years that any attempts have been made to carry out laboratory tests on the relative toxicity of wood preservatives. The pioneer in this field of research was Malenkovic, who in 1904 carried out tests by injecting wood with a preservative, and also made a few beaker tests; but as chance contaminants were depended upon, the results obtained are purely of historic interest. In 1910 Netzsch carried out tests on fluorin compounds. He injected wood blocks, but, in addition, employed sterilized gelatine medium in flasks and definitely inoculated the medium, employing *Penicillium glaucum* and also a wood-destroying fungus, namely *Coniophora cerebella*, as test fungi. Netzsch's work was followed by that of Seidenschnur, who in 1911 made comparative tests on the toxicity of zinc chloride and some of the tar oils. Gelatine medium was also employed in test tubes, and the mould *Penicillium*

glaucum used as the test fungus. In the same year (1911) Weiss tested creosotes in an agar medium, using yeasts, bacteria, and *Penicillium*. Rumbold (also in 1911) made agar tests in Petri dishes. He mixed the medium and preservative before sterilization and therefore lessened the value of the tests. In addition he carried out tests, using toasted bread, but such a test is not comparable to that employing agar medium owing to the fact that the starch would act as a diluent. In 1912 Falck carried out tests on agar medium, employing wood-destroying fungi, and Dean and Downs in the same year first employed creosote emulsion, using gum arabic as an emulsifier. In 1915 Humphrey and Fleming (1) published results of a number of agar tests, and the technique they employed is similar in most respects to that used by workers up to the present time.

AGAR TESTS.

A series of known concentrations of the preservative to be tested are added to a nutrient agar medium, and the whole poured into a sterile Petri dish. On solidifying, this medium is inoculated from an actively growing culture of the fungus chosen for use in the test, one dish contains only the nutrient agar to act as a control. The choice of the series of concentrations has to be based on the probable toxic value of the individual preservative. The plates are kept in an incubator under constant conditions and a time limit is set for the test, usually one month. At the end of this period, if the range of concentrations chosen covers the toxic point, the amount of fungous growth will be found to form a series ranging from extensive growth on the control plate to no growth on the higher concentrations. If the variation in concentrations was not sufficiently close, it may be found necessary to repeat the test, bracketing between that concentration which shows some growth and that which has inhibited all growth of the fungus. The minimum concentration of the preservative inhibiting all growth of the fungus is the figure taken as the efficient toxic point of the preservative for comparison with similar tests using other preservatives, though it is more accurate to quote both the concentration on which slight growth takes place and also that on which no growth takes place. The concentration that stops all growth does not of necessity kill the fungus, so in order to ascertain what is, strictly speaking, the toxic point, subcultures should be made on to fresh nutrient agar and incubated at the optimum temperature for growth of the test fungus for a period, when it will be seen whether growth has merely been inhibited or whether the mycelium has been killed.

If the fungus chosen for test is one that forms secondary spores, the concentration which kills the mycelium may not be sufficient to kill the spores. The choice of the fungus for test will be discussed later. The nutrient medium which has been found to be most satisfactory for the growth of the majority of the wood-destroying fungi, is a 2 per cent. malt extract medium. This medium is made up and sterilized in an autoclave. In the case of a water-soluble preservative, it has been found more satisfactory—in order to eliminate the sterilization of the preservative which might alter its toxic properties—to

make up a high concentration in distilled sterile water and to add this to the nutrient agar when still just liquid, then to mix and quickly pour. In any case the preservative and medium should on no account be mixed prior to sterilization, as this method sets up reactions between the medium and preservative which may alter the toxicity of the preservative to a considerable extent. If it is intended to sterilize the preservative, this should be done separately to the medium in clamped stoppered bottles and intermittent steam sterilization employed; but with careful manipulation there is no need for this, and the less the preservative is exposed to heat treatment the better.

In using tar oils and similar preservatives, it is first necessary to emulsify the preservative, and the choice of a suitable emulsifier and the making of a fine emulsion introduces further complications. Gum arabic has been found to be a suitable emulsifier as, contrary to the opinion of some workers, we have not found that in itself it alters appreciably the toxicity of the preservative: its only objection lies in its viscosity, which makes it difficult to avoid leaving traces behind when mixing the emulsion with the nutrient agar, thus throwing out the concentrations. Turkey red oil appears to be quite as good an emulsifier and has not the objection of viscosity. Neither of these agents appear to affect the growth of the fungus nor do they alter the toxicity of the preservative.

WOOD BLOCK TESTS.

The wood chosen for comparative tests should be matched, as far as possible being of even growth, as the test is not one for the durability of the wood, but as a relative test of the preservatives. The wood must naturally be one which the fungus readily attacks, so that usually sapwood is preferable to heartwood. Owing to the need of securing uniform penetration throughout the block, the species chosen should be one which treats easily. Some samples should be examined after treatment in order to ascertain the distribution of the preservative.

The blocks are first oven-dried and the dry weight noted. They are then treated in a small cylinder in wire cages under pressure, using varying concentrations of the preservative, and the absorption figures worked out. After treatment the blocks are transferred in the cages to an oven under as sterile conditions as possible, and dried down until the moisture content reaches approximately that of fibre saturation point, in order to bring them to a condition suitable as regards their moisture and air content for fungus attack. (The cages are attached to a spring balance so as to minimize handling.) The test blocks are directly transferred from the oven to the special culture flasks. These flasks should be inoculated previously with the test fungus.

To inoculate the blocks directly with a portion of agar from a culture is not a fair test, and attack is quicker and much more sure when the wood is placed on the fungus, as inoculation is effected over the whole surface of the block in contact with it, and, in addition, there is no shock to the fungus through the severing of the hyphae in transference, or in the drying up of the inoculum.

In order to avoid any possible effect of some of the preservative leaching out into the medium, some workers raise the blocks above the surface of the medium either by means of a thin lath of wood or by placing them on a small glass support; but although this has been tried out, we have found that, as a rule, the effect of leaching out is inappreciable, and the advantages both of easy handling and of direct contact, with consequent more vigorous infection, outweigh any advantage gained from the former method.

The flasks are incubated at constant temperature, and after a period of 4 months the blocks are removed from the flasks, oven-dried, and weighed. The loss in dry weight is taken as the measure of attack, the untreated blocks at the same moisture content acting as controls. Some workers have chemically analysed the blocks, but the figure for loss in weight is quickly obtained and gives an accurate comparison.

ADVANTAGES AND DISADVANTAGES OF THE WOOD-BLOCK TEST AND AGAR TEST.

Wood is the natural substance on which the fungi to be tested grow, and in which the preservative to be tested is to be used, and therefore, it is said, should give a more practical answer to the question in hand; on the other hand, the advocates for the agar test say that no two samples of wood are the same, and that it is impossible to ensure a perfectly even distribution of the preservative throughout a block. Moreover, the difficulties of ensuring sterile conditions are greater. In addition, the time taken to complete a test is longer and the determination of an exact end point more difficult. They point out that in any case these tests are merely comparative, and that this can be obtained more quickly and accurately by means of an agar test, also that figures obtained from such a test do at least give an accurate comparison of the relative value of one preservative as compared with another. Unfortunately the whole subject has been somewhat obscured by the fact that up to the present no standard method of testing wood preservatives has been adopted, so that in consequence the results obtained by different workers in this field have not been strictly comparable. I am glad to say that, owing to the energies of Dr. Hermann von Schrenk, this state of affairs is well on the way to being remedied. He called together at Berlin what really amounted to an international conference of workers in this field, and, as an outcome, a committee has been formed. This committee has made certain suggestions as to the rules of procedure in carrying out tests which have been adopted by those attending the meeting.

The difficulties involved in making standard tests are numerous. To begin with, each fungus may react in a different manner to each preservative, so that, for instance, although preservative 'A' may be found to be twice as toxic to fungus 'X' as preservative 'B', the case may be reversed if their action is tested against fungus 'Y'. In some cases a different strain of the same fungus, e.g. *Coniophora cerebella* may show very different resisting powers. In addition, the difference of the nutrient medium used may alter the concentration required. It will be seen, therefore, that any results to be comparable should

not only give details as to the exact constitution of the medium and method of preparation, but should state the name and strain of the fungus used for test. Many of the results obtained have lost most of their value from the fact that no mention of the name of the fungus has been given, or from the fact that a mixed culture had been used. Another difficulty in the wood block tests is to ensure even distribution of the preservative, and this is particularly the case in treating blocks with oils. The physical constitution of the medium may also alter the results (this is particularly applicable in cases where sawdust is employed), the differences in absorption of certain constituents of the preservative coming into the question, and is also very marked in wood blocks, especially when using mixtures of salts and oils or in emulsions, as absorption may be selective, and although it may appear that an even distribution has been secured, it is possible that the toxic elements of the preservative may have become concentrated in one area and thus give a false value. The importance of obtaining a perfect and fine emulsion is also great, and the emulsifying agent must be one which in itself is non-toxic, thus not affecting in either way the toxic properties of the preservative to be tested. The effect of sterilization is also one of great importance, and the use of heat sterilization has to be carefully guarded against; this is another difficulty encountered in this work, as only by very careful manipulation can contamination by mould be prevented. I have often seen it stated that the presence of moulds does not matter, as it shows that the preservative being tested is not an efficient one if moulds can grow actively on it, indeed, as will have been noticed in the brief historical account, most of the earlier workers in this field employed moulds such as *Penicillium glaucum* as test fungi. Results from such tests are valueless if they are to be applied to preservation against wood-destroying fungi, as will be understood when it is stated that many of these mould fungi appear to thrive on heavily creosoted timber. In addition, their growth is often extremely rapid and may in some cases entirely inhibit the growth of the test fungus.

The choice of a suitable test fungus is important. In America, where the agar test is favoured, owing to the fact that it can be more easily standardized and its results more quickly obtained, *Fomes annosus* is usually employed, as this fungus has been found to be highly resistant to wood preservatives and probably for an agar test it is one of the best species to employ. The toxic point is taken as that concentration between which slight and no growth takes place, and usually the actual killing point is also ascertained as mentioned earlier. In wood-block tests, where visual estimation of the amount of growth is impossible and results have to be based on loss in dry weight, *Fomes annosus* has proved to be unsuitable, as the losses in weight caused by this fungus are slight as compared with those caused by many other fungi. For such tests the fungus chosen should be one that readily attacks the species of wood used, and one, moreover, that causes a rapid loss in weight of the wood substance.

Some fungi suited to this purpose are *Lentinus lepideus. Lenzites abietina, Coniophora cerebella* in the case of softwoods, and *Polystictus versicolor* in the case of many hardwoods, especially in that of beech.

TESTS ON VOLATILE SUBSTANCES.

Tests on volatile substances are best carried out by suspending a container of the preservative in an inverted culture flask which contains an active growing culture of the fungus and noting the effect on its growth. Not much work has so far been carried out at our Laboratory on such substances. Their effect is naturally somewhat transient owing to their volatile nature, though if penetration of the vapour throughout the wood can be secured, they might prove of great value in killing off fungus in timber in houses without removal of the timber and where heat sterilization is impossible. This would be of great use in the earlier stage of an attack. Formalin vapour is probably as efficient as any of this class.

SERVICE TESTS.

Although laboratory tests may give much useful information, especially for comparing the relative value of wood preservatives, and the wood-block tests give some idea as to the concentrations necessary for commercial use, in order to obtain reliable data as to their value in practice it is necessary to supplement such tests by service ones, since it is impossible to reproduce in the laboratory the exact conditions to which timber may be exposed when in practical use. Moreover, although severe leaching tests can be carried out in the laboratory, it is difficult to imitate all the varying factors that act on the wood under service conditions. In addition, to the practical man a large scale demonstration is always more convincing than laboratory experiments. For this purpose large specimens are treated with different preservatives and placed in the ground alongside untreated matched specimens, the latter acting as controls.

In order, as far as possible, to take into account varying soil conditions, repeat series are located in different sites having varying soil and possibly climatic conditions. The specimens are placed in the ground, thus being under identical service conditions to those to which fencing and gate-posts are subjected. Periodic inspections are made and the life of the specimen noted.

For the further testing of water-soluble salts a constant temperature chamber, in which humidity is kept as near saturation point as possible, has been erected at the laboratory. Specimens treated and untreated are placed on slate racks, each one being inoculated with a piece of infected wood tacked to the surface.

FUNDAMENTAL WORK.

So far the greater part of the work on wood preservation has been more or less of an empirical nature, though the zinc meta-arsenite process was based on fundamental principles from knowledge of the chemical action of the fungi attacking wood, and other attempts of a similar kind have been made.

It has generally been considered essential that a preservative should be directly toxic to fungus growth, and tests have been made on this assumption, but is this really essential? Is it not possible that having discovered the chemical action of a fungus on wood, such knowledge could be made use of in

the ideal preservative by preventing or neutralizing the reactions between fungus and host, namely wood, thus starving the fungus? I think that it is highly probable that the constitution of the ideal preservative will be based on a knowledge of such chemical processes rather than of its being merely poisonous. Shut a man up in a cage with food in sight, but not attainable, and the result will be as inevitable as if poisoned food were provided. It may be argued that the advantages of the use of preservatives at present marketed are that the bye products of industry can be got rid of often at high profit, and that these are a great financial asset to those concerned. Apart from the fact that it is quite as probable that the manufacture of the ideal preservative will also involve the use of bye products, it must be emphasized that from a national point of view the conservation of timber supplies are of paramount importance and should take precedence.

If every fungus acted in a different manner such a line of approach would be impracticable, but it appears highly probable that the chemical reactions involved are by no means so varied, and that, therefore, the possibilities of such a preservative proving effective against all wood-destroying fungi are good. There remains a large field for research on such lines. Chemical research into the true nature of the variation in natural durability of different timbers should throw light on the subject of wood preservation—the chemical nature of their extractives, &c. It is not accurately known what are the toxic agents in many of the well-proved preservatives and in what way they act on the fungus. In this connection we are at present carrying out separate tests on various fractions obtained from low temperature tar distillation with a view to throwing further light on the reason for the high efficiency of creosotes and such-like preservatives. Much more efficient penetration might be obtained from the use of a less complex substance than when using a mixture or compound, many of the constituents of which may simply retard penetration and may also even lower the toxicity of the whole.

Although very little is known as to what determines the toxicity of a preservative, it appears to be established that in the case of the salts of heavy metals, such as copper and mercury, it is the metallic ion that is largely effective. In the case of strong acids, as for example HCl and H_2SO_4, the hydrogen ion is thought to be the toxic element (2); carboxyl hydrogen appears to be more toxic than hydroxyl hydrogen. In phenols this latter combination occurs, and, as these do not ionize, the toxicity appears to be due to the undissociated molecule. The number of hydroxyl groups seems to have little influence, but the introduction of a methyl group into the benzene nucleus increases toxicity. The presence of nitro groups likewise increases the toxicity, and Falck states that nitro and di-nitro phenols are considerably more toxic than phenol, and more so in the ortho than in the meta or para position. Netzsch found that the fluorin ion was also very active.

Finally, I believe that, although not of immediate practical use, the chemical line of approach is a most hopeful one, and, although it is a study beset with great difficulties, it will in the future lead to the finding of the ideal

preservative, which stops fungus decay, is not leached out, penetrates the wood with ease, and has all the other attributes required for the purpose of conserving the wood supplies of the world in the most efficient and economic manner.

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NOTES ON THE CARPATHIAN *URWALD*

BY W. L. TAYLOR

(Forestry Commission)

THERE are still about 1,000,000 hectares of virgin forest remaining in south-eastern Europe, and roughly half of this area lies within the boundaries of post-war Roumania, whose total forest lands now extend to no less than 6,500,000 hectares which, together with a further 725,000 hectares of clearances, represents 24·5 per cent. of the area of the country. Very large tracts of forest lie in the region of the Eastern Carpathians, considerably more than half of it covering the declivities of the main and subsidiary mountain ranges of Transylvania. Investigation during a short leave is of necessity local, and it is only by the courtesy of the management of the Timber Exploitations Company, Foresta Romana, of Bucharest, and the helpful guidance of Herr Forstrat Inq. Jul. Fröhlich of Reghin in Transylvania, that it becomes possible to write these notes.

LOCATION AND TOPOGRAPHY.

The forests inspected are situated on the slopes of the *Kaliman Hargita Gebirge* (6,897 feet) in the Eastern Carpathians, and the centres chosen were Reghin and Salard in the valley of the Muresh river, a tributary of the Theiss and of the Danube, which rises in the Ghirgiu range and has a total length of 544 miles. It is navigable by small rafts of timber in spring and early summer. Northward around the flanks of the Kaliman massif the forests extend to 100,000 hectares. From Salard on the south side of the Muresh valley the forest of Tanscal stretches southwards in the direction of Ghirgiu and covers a total area of about 40,000 hectares. The southernmost side of this forest tract was formerly the property of the ill-fated Crown Prince Rudulf. The portion known as the forest of Salard extends to 6,000 hectares and is bounded on the north by the River Muresh. The area has been cut over largely and a considerable extent of the devastated land has been replanted. To reach the virgin stand (*Urwald*) a journey of 19 kilometres from Salard is necessary, partly by forest railway and partly on foot, and, at an elevation of 1,450 metres above sea-level, the remnant of the primeval spruce forest of this locality is reached, itself marked for early exploitation.

The terrain is one of decidedly narrow and moderately steep-sided valleys, closely grouped, frequently forking and penetrating far inwards from the Muresh valley towards the watershed. The general direction of these valleys is north and south, and the mountain streams and torrents on the Salard side of the watershed all flow northwards to feed the Muresh river. None of these minor streams is of use as a means of water transport.

CLIMATIC CONDITIONS.

The climate is continental in its severity. Winters are harsh and endure for as long as five months of the year. Snow-fall is usually heavy, especially in the month of February, and snow will at times lie well on into the month of April. Spring is a short season and merges hardly perceptibly into summer, when a considerable degree of heat is experienced. The autumn is a long one and lasts well into November. The mean annual temperature is about 6° C.; extremes of temperature lie between 35° and minus 30° C. but the incidence of frost does not appear to be a matter of great concern in the forestry of this part of Transylvania, although frost has been recorded on 120 days in the year. The two most prevalent winds are the *Crivetz* from the NE. and E., and the *Austru* from the W. and SW. During spring and early summer the former, drawing its moisture from the Black Sea, brings a considerable quantity of rain. The *Austru* is for the most part a dry wind. The rainfall averages 800 millimetres per annum and the season of heavy rains is the early summer, mid-May to mid-June being usually the period of greatest precipitation. Roumania as a whole has a comparatively low rainfall, the annual mean at Bucharest being only 560 millimetres.

GEOLOGY AND SOILS.

The core of the Eastern Carpathian Mountain System is composed of igneous and metamorphic rocks: granite, gneiss and schists, with quartz and other intruders. The solid geology of the Salard neighbourhood is Andesitic and the formation is often overlaid, on the lower slopes, by a considerable stratum of conglomerate. The derived soils are fine, crumbly, well-aerated loams and grit-sands, sometimes with stones and small boulders below. The leaf-fall of long ages has converted the surface into a very fertile forest soil, the value of which is well recognized by the foresters of Roumania. Rock outcrop and precipitous bare cliffs occur on the flanks of the Kaliman massif, but not in the forest area to the south of Salard.

In places at 1,600 metres and above, a 5-inch layer of sour humus, close and cheesy in consistency and devoid of aeration, was observed under virgin spruce, a factor which interferes to some extent with natural regeneration except where the layer is broken up by the treading of deer and the wild boar. Natural regeneration occurs most freely in the places which have been subjected to these forms of 'cultivation' and, after the manner of the spruces in other parts of the world, along the lines of the fallen and rotted stems of the dead trees. On the whole, soil conditions are favourable, the soils being fresh and humid and possessed of excellent but not excessive natural drainage.

VEGETATION.

In the valley bottoms weed growth in June is lush, but at the higher levels, and under the more or less complete canopy, ground vegetation becomes sparse, or only mosses, ferns, and a few apparently unimportant shade bearers. The species to be observed along the main valley from Salard include:

Verbascum spp., *Doronicum* sp., *Epilobium angustifolium*, *Digitalis* sp., *Ranunculus* spp., *Rubus* spp., *Fragaria vesca*, *Valeriana officinalis*, *Echium vulgare*, *Sonchus* sp., *Arctium lappa*, *Vaccinium Myrtillus*, *Dactylis glomerata*, *Avena fatua*, *Aira caespitosa*, *Poa* spp., *Festuca sylvatica*, *Brachypodium sylvatica*, *Luzula* sp., *Carex* sp., *Pteris acquilina*, *Aspidium* sp., *Polytrichum* sp., *Lycopodium* sp.

Fire weed (*Epilobium angustifolium*) and a gaudy, pale yellow, *Verbascum* flourish over wide areas of the cleared slopes, but the *Filices*, especially bracken fern, are scarce. Wild raspberry grows freely in places and is regarded as a most favourable soil indicator. None of the *Ericaceae* was actually observed, but heaths are included in the flora of the highest elevations.

TIMBER.

The species of economic value of this region are *Fagus sylvatica*, *Picea excelsa*, and *Abies pectinata*. The last-mentioned tree occurs, however, only as scattered specimens at Salard, and nowhere in the Eastern Carpathians is it very strongly represented. Other broad-leaved species which occur sparsely and mainly in the valley bottoms, and on the lower slopes, are *Ulmus montana*, *Tilia europaea*, *Acer pseudo-Platanus*, *Alnus glutinosa* and *A. incana*, and *Taxus baccata*, while at extreme elevations are to be found *Pinus plumilio*, *Juniperis* spp. and *Rhododendron ferrugineum*.

The forest lies wrapped around the contours of the mountains in broad and fairly well-defined zones:

Elevation.	*Species.*
600 to 1200 metres.	*Fagus sylvatica*, pure and in mixture with *Picea excelsa* and *Abies pectinata*.
1200 to 1400 „	*Picea excelsa* with a few *Abies pectinata*.
1400 to 1700 „	*Picea excelsa* pure.
Above 1700 „	*Pinus plumilio*, &c.

It is to be noted that pure stands are natural and by no means rare in the Carpathian *Urwald*. The effects of naturally pure stands on the soil cannot here be unfavourable, or these forests of pure beech and spruce could not have endured and prospered for many thousands of years. Up to 1,300 metres or so above sea-level, there is in places a moderately dense underwood composed of a variety of species including *Sambucus niger* and *S. racemosa*, *Corylus avellana*, *Populus tremula*, *Acer campestre*, *Viburnum opulus*, *Pyrus* spp. and *Salix caprea*. Above this elevation, however, underwood, where existing at all, is sparse. The oak of the Carpathians, *Quercus pedunculata* and *Q. sessiliflora*, are not included in the *silva* of the immediate region of Salard, but elsewhere, below 600 metres, there were formerly some large and valuable stands. Exploitation has been severe, and it is stated that commercially on a large scale Carpathian oak is now almost a thing of the past. *Larix europaea* is not locally an indigenous species, nor, it was stated, is this tree native of the mountain ranges of the Eastern Carpathians.

From the beech zone upwards clear felling has left its mark, and the surviving stand of primaeval spruce at Salard is not entered until after the 1,450

metre contour is passed. *En passant* it may be remarked that the optimum conditions for the species are found between 1,200 and 1,500 metres above sea-level. The stand is, of course, uneven-aged, and at first glance appears very openly spaced. The age classes are not by any means evenly represented, and a somewhat patchy appearance results, but nevertheless the canopy is actually fairly complete.

Virgin spruce in pure stands occurs extensively in the Kaliman-Hargita Gebirge, in north-east Transylvania, in south-east Bukovina, in the Kilibaba region, and from an elevation of 900 metres in south-east Transylvania.

At 1,500 metres and over there are from 160 to 300 sizeable stems to the hectare; an average of 25 per cent. of the total stand is unfit for cutting, being dead, diseased, or ill-grown. Production here amounts to from 300 to 600 cubic metres per hectare of timber in the round.

The Transylvanian type of *Picea excelsa* is known in Eastern Europe as the *Siebenburgen Fichte*. It is neat in appearance with short branches, even on exposed edges of the forest and in the open. The form is narrowly pyramidal and almost cypress-like, approximating somewhat to the Serbian spruce, *P. omorika*, in general appearance, but without the specific characters of this species, e.g. the *Siebenburgen* spruce bears the typical 5-inch cylindrical cone of *P. excelsa*, and not the short, almost egg-shaped cone of *P. omorika*. The type is a remarkably regular one, and on the whole the stems are far from being rough and knotty. The rate of height growth appears to be good, and annual rings of one millimetre in width are the average in Salard forest. Rates of increment vary as might be expected even in groups of apparently even-aged trees, with corresponding variation in the strength and quality of the timber. Diameter classes here, as elsewhere, are not a matter of age so much as of light and spacing. Even-aged groups covering any considerable extent of ground are rare. It was stated that a satisfactory proportion of prime quality timber is converted and that Salard forest has yielded a large quantity of high-grade sounding-boards (*resonanz-holz*) for the piano trade in Germany.

The natural age cycle in the primeval spruce forest is approximately 300 to 350 years. At the extreme age single stems may attain a diameter of one and a half metres and a height growth of 56 metres in the optimum zone, where the total content of the stand has been recorded as being as much as 1,300 cubic metres to the hectare, but this quantity can only be regarded as exceptional in view of the average for the forest of from 500 to 700 cubic metres per hectare. The largest spruces are always to be found in the zone of mixed beech and conifers and not among the pure stands. The same remark applies to the qualitative value of the timber produced. As the trees age they fall victims to fungi, insects and gales. The remains of fallen giants, in all stages of final decay, are frequently to be seen on the forest floor and, as already stated, natural regeneration occurs most readily along the lines of the rotted tree trunks on the ground. The reduction of one of these large spruce stems by the processes of nature occupies as long a period as fifty years. It was of interest to hear the

confident assertion that seed collected from these forest giants is equal in fertility and weight to seed gathered from the younger spruce, and that the opinion repeatedly expressed in forest literature that very old trees bear barren or inferior seed is not in accord with the observed facts regarding the seeding of spruce in the Carpathian *Urwald*.

RISKS AND DANGERS.

The chief of the injurious insects are *Hylobius abietis*, *Myelophilus piniperda*, *Tomicus* spp. and *Sirex gigas*. In the primeval forest disease is seldom catastrophic, as it may be among artificial plantings. Of the fungi, *Melampsorella elatina* leaves its mark on the silver fir, and *Trametes pini* causes considerable damage to spruce both in the mixed and pure stands. *Fomes annosus* is regarded as the principal and normal cause of the death of conifers in the *urwald*. Up to 20 per cent. of the stems are usually affected, and the incidence of this destructive fungus is thought to have some close and unexplained connexion with soil conditions. *Armillaria mellea* is described as unworthy of mention as an injurious factor. In the beech forest, both in the pure and mixed stands, *Polyporus fomentarius* occurs, but generally among the beech trees which have passed their prime. It is noticeable that the beech, where forked, are almost always black-hearted, and a disease known locally as 'black bough' affects spruce at the upper limits of its growth approaching the timber line.

Ring shake in spruce is attributed to uneven growth, as shake occurs where the narrow ringed wood impinges upon wider annual rings. The natural selection system imposed by the struggle for existence in the primeval forest and the liability to sudden exposure to light account for this consequent irregularity of increment. Spruce stems also tend to twist on rocky, shallow, and exposed ground.

The plague of the rabbit is not inflicted upon foresters in this part of Europe. The brown hare is indigenous, but the rabbit is non-existent, and, so long as the bear, wolf, lynx, fox, badger, and marten, not to mention the lesser carnivores, survive in Transylvania, no rodent, except possibly the squirrel, is greatly to be feared. Red deer and roe destroy a certain number of young trees each year by using them as fraying stocks for the purpose of ridding their antlers of the velvet. Damage is also done by capercailzie which are fairly common in the woods.

Lightning is the cause of certain losses in these forests, but on the whole, fire damage is inconsiderable, although a destructive fire occurred at Tiplitz-Romana some forty-five years ago when a crop on 300 hectares was destroyed. No system of fire protection is practised. Calamitous damage in the forest is occasioned mainly by gales, and from time to time both large and small gaps are torn out by winds. Wholesale windfall is, however, speedily regenerated by means of the normally abundant seed-fall of the succeeding seed year from the surviving stands in the vicinity. *Hylobius abietis* may become troublesome after any extensive windfall. Snowbreak is not a very serious hazard nor are floods and wash-outs locally of a destructive nature. Landslides only occur

where re-afforestation has been neglected, as on some of the areas definitely thrown open to the peasant graziers and not intended again to be stocked with trees, and throughout Roumania a total of 800,000 hectares of forest land has been expropriated and devoted to this purpose. Otherwise grazing is not a troublesome complication, and the only form of wilful damage to be mentioned is the propensity on the part of unauthorized seekers after suitable types of wood for splitting into shingles to cut test holes in the large spruces at breast height. Rejected stems which have been subjected to such treatment and left standing usually become prey to fungi and perish.

DAVID DOUGLAS

BY J. M. MURRAY

DAVID DOUGLAS was born at Scone in Perthshire on the 26th day of June, 1799. His father was a stone-mason, and the education of young Douglas at the parish school of Kinnoull was of the standard customary for rural youth in Scotland at that time. The duration of school days was short, but the pupils received a good grounding in the three R's, and frequently a definite strengthening of character which helped them greatly in later years. Douglas appears to have left school at about the age of 11 to commence a seven years' apprenticeship as a gardener in the gardens of the Earl of Mansfield at Scone Palace. It is recorded that Douglas was then independent, active, and mischievous, but when some of the other boys complained to Beattie, the head gardener, the reply was 'I like a deil better than a dolt'. Douglas had an interest in his plants.

In 1818 when about 18 years of age he moved to the gardens of Valleyfield near Culross. In these gardens, which were then owned by Sir Robert Preston, Bart., there was a large collection of exotic plants. Sir Robert was an enthusiastic gardener who owned a library of botanical books to which Douglas was allowed access. After two years' service at Valleyfield, Douglas obtained an appointment in the Glasgow Botanic Garden. Dr. (afterwards Sir William) Hooker, who was then Professor of Botany in the University of Glasgow, was attracted by the enthusiasm of Douglas for plants and made him his companion on excursions to the Highlands which he was then making to collect materials for the *Flora Scotica* on which he was engaged. At the age of 23, after two years' service in the Botanic Garden, Douglas was recommended by Dr. Hooker to the Royal Horticultural Society as a suitable person to employ as a plant collector. The first proposal was to send him to China, but the unsettled state of that country caused a change to be made, and Douglas was instructed to proceed to North America.

From letters left by Douglas it would appear that the main object of this expedition was to procure living plants for the garden of the Horticultural Society, and from 4 August to 10 December 1823 he was engaged in collecting and purchasing plants on the Atlantic sea-coast for this purpose. On the 5th of January 1824 Douglas returned to London, and the main matter of interest to the forester remaining from this, his first American expedition, is a number of notes on American oaks.

While in London awaiting a further commission, Douglas is reported to have spent as much as eighteen hours per day in remedying those matters in which he considered himself defective as a collector. On 25 July 1824 he embarked on a ship belonging to the Hudson Bay Company and destined for the Columbia River. Dr. John Scouler had signed on with this ship as surgeon in

order that he might further his pursuit of natural history, so that in his companion for the long voyage round the Horn Douglas was fortunate.

Landing on the coast at Cape Disappointment in company with Dr. Scouler on the 8th of April 1825, after a 'long and tedious voyage of 8 months 14 days from England', Douglas made his first acquaintance with a country whose coniferous flora later made his name known to botanists, foresters, and aboriculturists for all time to come. The country to which he came was one not well known to the white man. Trading camps had been formed here and there, and parties from these travelled over considerable distances, but great tracts were still unexplored and peopled by hostile, or at least highly suspicious, Indians. Vancouver with his companions, including Archibald Menzies, had visited the coast almost a quarter of a century before, and something was known of the giant tree flora that awaited the collector.

Among the first plants mentioned by Douglas were *Pseudotsuga taxifolia* and *Tsuga Albertiana*. The size of the former was always to him a matter of wonder. His earlier experience on the eastern coast led Douglas into blunders with species on the west. He thus mistakes *Tsuga Albertiana* for *Tsuga canadensis*, *Larix occidentalis* for *Larix europaea*, and *Thuja gigantea* for *Thuja occidentalis*. The last error he corrected at a later date and named the western species *Thuja Menziesii*, although this name was afterwards not found to be valid.

In April 1825 Douglas records as No. 11 of his collection '*Alnus* sp.; a tree 50 to 70 feet high; may prove *A. glutinosa*, its size occasioned by the richness of the soil and fine climate, moist places on the Columbia'. This may have been *Alnus oregona*. The large size and beauty of *Acer macrophyllum* attracted him also, and he records that on the Columbia River it reached 16 feet in circumference and 90 feet in height. Previously described by Pursh, this tree was introduced to this country by Douglas who sent seed in 1825. At this time also he records the discovery of a species of *Taxus* (*Taxus brevifolia* Nuttall), although no seed was sent by him. It was not until 1854 that this tree which is still comparatively rare in Britain was introduced by William Murray.

On the 19th of July Douglas set out on a journey of twelve days 'principally for the purpose of searching for and inquiring after the tuberous rooted *Cyperus* . . . which is said to afford the natives food something like potatoes when boiled'. He was unsuccessful and had an uncomfortable time. He writes: 'Now I have a little idea of travelling without the luxuries of life. Only two nights were dry during my stay on the shore; before I could lie down to sleep my blanket drying generally occupied an hour. . . . With a basin of tea, a small piece of biscuit, and now and then a duck, I managed to live very well.'

Troubles with Indians do not appear to have been numerous, although some did occur. One instance is associated with the discovery of a pine, the grandest in North America, to which at a later date Douglas gave the name *Pinus Lambertiana*. Rumours of this pine had reached him and he had also

seen its seeds in the smoking pouch of an Indian in August 1825. In October 1826 he made his second excursion in search of it, the first having been unsuccessful. He had as companion an Indian youth who was employed in drying paper. The description given by Douglas of finding the pine is worthy of repetition:

'At midday I reached my long-wished *Pinus* (called by the Umpqua tribe *Nàtele*), and lost no time in examining and endeavouring to collect specimens and seeds. New or strange things seldom fail to make great impressions, and often at first we are liable to over-rate them; and lest I should never see my friends to tell them verbally of this most beautiful and immensely large tree, I now state the dimensions of the largest one I could find that was blown down by the wind: Three feet from the ground, 57 feet 9 inches in circumference, 134 feet from the ground, 17 feet 5 inches, extreme length, 215 feet. The trees are remarkably straight; bark uncommonly smooth for such large timber, of a whitish or light brown colour; and yields a great quantity of gum of a bright amber colour. The large trees are destitute of branches, generally for two-thirds the length of the tree; branches pendulous, and the cones hanging from their points like small sugar-loaves in a grocer's shop, it being only on the very largest trees that cones are seen, and the putting myself in possession of three cones (all I could) nearly brought my life to an end. Being unable to climb or hew down any, I took my gun and was busy clipping them from the branches with ball when eight Indians came at the report of my gun. They were all painted with red earth, armed with bows, arrows, spears of bone, and flint knives, and seemed to me anything but friendly. I endeavoured to explain to them what I wanted and they seemed satisfied and sat down to smoke, but had no sooner done so than I perceived one string his bow and another sharpen his flint knife with a pair of wooden pincers and hang it on the wrist of the right hand, which gave me ample testimony of their inclination. To save myself I could not do by flight, and without any hesitation I went backwards six paces and cocked my gun, and then pulled from my belt one of my pistols, which I held in my left hand. I was determined to fight for life. As I as much as possible endeavoured to preserve my coolness and perhaps did so, I stood eight or ten minutes looking at them and they at me without a word passing, till one at last, who seemed to be the leader, made a sign for tobacco, which I said they could get on condition of going and fetching me some cones. They went, and as soon as out of sight I picked up my three cones and a few twigs, and made a quick retreat to my camp, which I gained at dusk. The Indian who undertook to be my last guide I sent off, lest he should betray me. Wood of the pine fine, and very heavy; leaves short, in five, with a very short sheath bright green; cones, one 14½ inches long, one 14, and one 13½, and all containing fine seed.' Here appears the courageous pioneer who, whenever the risk is over, can at once change back to the observing and recording man of science.

On 21 March 1827 the annual express across the continent from Fort Vancouver to Hudson Bay set out. A trail had been blazed, but it was the end

of August before Douglas reached the eastern terminus at York Factory. During this long journey he collected plants, animals, and birds. Of the birds he regrets the death by suffocation of a Calumet Eagle which he had conveyed alive over 2,000 miles. Douglas made the return journey to Britain in company with the Franklin expedition.

It cannot be said that his time in London was pleasant. Welcomed by those who knew him, he was happy. Later he was taken out into society, particularly by Mr. Sabine, the Secretary to the Horticultural Society, and much was made of him and his adventures. To be lionized became distasteful, and Hooker, who was his friend, says he soon found he had been pursuing a shadow instead of a reality. He found relief when, after two years, he was in 1829 again commissioned by the Horticultural Society as a plant collector in the interior of California and to the northern boundary of Mexico. He was also employed by the Colonial Office to take observations on magnetic and atmospheric phenomena. Douglas himself had formulated the idea of proceeding from North America to the opposite shore and working the Russian frontier with China, and towards this end he corresponded with certain Russian ministers. He also proposed collecting skulls and bones of animals *but not of men*. His knowledge of the attitude of the Indian towards his dead was the cause of the exception. He also had in mind the Indian threat to Dr. Scouler's life on account of two Chenook skulls he had taken.

Unfortunately the regular record of events as they happened in this expedition is not preserved, and the observations of the naturalist are available only from certain letters written to friends. A daily record was kept, but in a disaster on the Fraser River (13 June 1833) this was lost along with many specimens and seeds. At the same time Douglas almost lost his life. In this third expedition Douglas discovered so many conifers that he was at one time constrained to write, 'you will begin to think that I manufacture pines at my pleasure'. He also speaks of travelling for three weeks in forests of *Abies nobilis* which he considered by far the grandest of the conifers. *Taxodium* he described as the great beauty of Californian vegetation. *Abies grandis* he considered to be like *A. balsamea* but larger. An interesting tree, the discovery of which is not usually credited to Douglas, is *Abies bracteata*. Writing from Monterey in December 1832 Douglas describes a beautiful tree which has deciduous cones 'with an entire bractea or scale exserted to 3 to 4½ inches'. This he found in lat. 36 in the high mountains of California. The name he proposed for it was *Pinus venusta*. Dr. Coulter, who met Douglas in Monterey, is frequently given as the discoverer of this tree. But neither Douglas nor Coulter collected seed, and it was not till 1853 that Lobb introduced it to Britain.

Many years after his death there were unearthed in the offices of the Horticultural Society notes in the handwriting of Douglas. These, on examination, proved to be descriptions of conifers which he had found. Certain sentences in these are of particular interest to foresters. *Pseudotsuga taxifolia* he says has a timber resembling larch, but 'If we judge from the quantity of

charcoal produced it will not prove so durable as the Larch'. He says *Picea sitchensis* resembles *P. Douglasii*, and although not so large as that species 'it may nevertheless become of equal if not of greater importance, as it possesses one great advantage over that one by growing to a very large size on the Northern declivities of the mountain in apparently poor, thin, damp soils; and even in rocky places, where there is scarcely a sufficiency of earth to cover the horizontal wide-spreading roots, their growth is so far from being retarded that they exceed one hundred feet high and eight feet in circumference. This unquestionably has great claims on our consideration as it would thrive in such places in Britain where even *P. sylvestris* finds no shelter. It would become a useful and large tree.' *Pinus contorta* was found by him only on the coast and he dismisses it with 'Little can be said in favour of this tree either for ornament or as a useful wood'.

Douglas visited the Sandwich Islands in 1832 and then returned to the Fraser River. In 1833 he finally quitted North America, having resigned his appointment as collector to the Horticultural Society in consequence of a belief that certain changes in the Society which led to the resignation of his friend, Mr. Sabine, were unfair to that gentleman. He then sailed for the Sandwich Islands and had been there for several months when on 12 July 1834 he met his death by accidentally falling into a pit in which a bull was already trapped. His body was buried in Honolulu and the place is marked by a stone tablet on the corner of the Coral Stone Church there.

It has been said that 'there is scarcely a spot deserving the name of garden, either in Europe or in the United States, in which some of the discoveries of David Douglas do not form the chief attraction'. So also to the forester many of the plants he discovered or introduced are of first importance. Memorials have been erected to him, but the monument by which he will be known most widely is the great Douglas fir forest of Western North America.

The following is a list of trees introduced by David Douglas: *Acer circinnatum* Pursh, *Acer macrophyllum* Pursh, *Crataegus Douglasii* Lindley, *Abies amabilis* Masters, *Abies grandis* Lindley, *Abies nobilis* Lindley, *Picea sitchensis* Carriere, *Pinus Lambertiana* Douglas, *Pinus insignis* Douglas, *Pinus monticola* Don, *Pinus ponderosa* Douglas, *Pinus Sabiniana* Douglas, *Pinus Coulteri* Masters, *Pseudotsuga taxifolia* Britton.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION CENTENARY MEETING, LONDON, 1931

SIR ALEXANDER RODGER was chairman of Section K* (Forestry) and Dr. E. V. Laing, Secretary.

The following is a list of authors and titles of papers:

Discussion on Wood Preservation.

(*a*) 'Research on Wood Preservation,' Mr. R. S. Pearson, C.I.E.

(*b*) 'Toxicity of Preservatives against Wood Destroying Fungi', Mr. K. St. G. Cartwright.

(*c*) 'Prevention and Control of Damage by Wood Boring Insects,' Dr. R. C. Fisher.

(*d*) 'Methods of Applying Wood Preservatives,' Mr. J. Bryan.

(*e*) 'A Chemical Approach to the Study of Wood Preservation,' Mr. W. G. Campbell.

'Forestry in the Empire during the last 100 years,' Sir Alexander Rodger, O.B.E.

'Empire Forestry during the past Decade,' Sir Roy L. Robinson, O.B.E.

'Empire Forests as a Resource,' Mr. Fraser Story.

'Afforestation Work in the Plateau Central of France,' Professor E. P. Stebbing.

'Site,' Mr. R. Bourne.

'The Culbin Sands,' Mr. J. F. Annand, O.B.E.

'Preliminary Stages of an Investigation into various Races of European Larch,' Dr. M. L. Anderson.

'British Forestry and the Philosophy of Action,' Dr. A. S. Watt.

'The Marketing of British Timbers,' Mr. J. S. Corbett, O.B.E.

'The Economic Aspect of Timber Utilisation,' Mr. J. R. Cosgrave.

'The Effect of Progressive Fungal Decay on the Mechanical Strength of Timber,' Mr. W. P. K. Findlay.

'Studies in the Biology and Forest Relations of the Pine Shoot Moth, *Evetria* (Rhyacionia) *buoliana*, Scheff., by the late Clement Cranshaw Brooks,' Dr. R. N. Chrystal.

SOCIETY AND OTHER NEWS

FOURTH ANNUAL EXCURSION

The members of the Society of Foresters met at the Falcon Hotel, High Wycombe, on the evening of the 30th of September 1931 to hold the fourth Annual Excursion in this district. Over twenty members attended part or the whole of the excursion. An interesting and instructive programme had been arranged occupying the three days of the excursion fully in the various studies planned for the occasion of this gathering. Leaving High Wycombe on the morning of the 1st of October, the party proceeded to Princes Risborough to inspect the Forest Products Research Laboratory, under the guidance of Mr. R. S. Pearson, C.I.E, F.L.S., Director of the Laboratory and President of the Society for the current year. The organization and activities of the Laboratory were explained.

Each section of the work was then visited by the party, who expressed interest in the wide range of work undertaken in connexion with Forest Products Research. Lunch was provided at the Laboratory through the kindness of Mrs. Pearson, who also invited the Senior Officers of the Staff and their wives to meet the visitors.

On the 2nd of October, by kind courtesy of the representative Directors, visits were paid to three of the leading firms engaged in the chair and furniture industry of High Wycombe. The first visit was to Messrs. Wm. Birch Ltd., the party being conducted round the works in person by Mr. P. J. Birch, who is a member of the Imperial Institute Advisory Committee on Timbers, and his brother Mr. W. H. Birch. Here the party had the opportunity of inspecting an extensive stock of home-grown timbers comprising oak, beech, and walnut, which are largely used by this firm in the manufacture of high-class chair and furniture products.

Besides the home-grown timbers mentioned, stocks of other well-piled woods were seen, such as West African mahogany, Quebec birch, American oak, walnut, and Canary whitewood; Polish and Austrian oak, Honduras mahogany, are also held, and, in addition, considerable quantities of plywood. After air seasoning between sticks the stock is passed to the seasoning kilns, and conditioned ready for use in the factory. The kilns used (and constructed in consultation with the Forest Products Research Laboratory) are of the central duct humidity type, fitted with reversible fans. These are designed for dealing with a wide range of species and of varying moisture content, and have performed efficient service. Proceeding to the well-equipped shops, replete with motorized direct-driven, up-to-date machinery, the various machine operations were explained in detail, and after visiting the finishing sections, bending department, and stock rooms the party reluctantly adjourned for lunch.

In the afternoon a visit was paid to the works of Messrs. E. Gomme Ltd, Mr. F. R. Gomme receiving and personally conducting the party round the extensive yards and workshops of his firm. Here the visitors saw the effect of the introduction of mass-production methods in furniture manufacture, from the receipt of the raw material to the output of the well-designed finished product, somewhat on American lines but carefully re-modelled to suit British conditions. The timber used is principally imported sawn stock comprising oak, walnut, African mahogany, and birch. The use of transfer bogies facilitates the handling of the incoming material from rail to yard, thence from yard to kiln, and from kiln to factory. For conditioning the sawn stock a battery of

up-to-date connection type humidity kilns give excellent results on the class of timber handled.

Proceeding to the woodworking shops, which are equipped with up-to-date machinery, designed for mass-production work on a layout to give extremely expeditious handling, Mr. Gomme explained to the party the operations involved and methods employed in producing high-grade furniture by these modern methods, evolved after a great amount of thought and experiment. The balance of machine operations was a very noticeable feature in this factory, which is one of the most recent in this country. On reaching the finishing sections and show rooms, the excellence of the finished products was revealed; many of these expressing ultra-modern design and finish.

The party then adjourned to head-quarters for tea, being joined by Mr. A. E. Barnes, Chairman of Messrs. Goodearl Bros., and President of the High Wycombe and District Furniture Manufacturers' Federation, Mr. P. J. Birch, and by Mr. Hubert Glenister of Messrs. Thos. Glenister Ltd., all of High Wycombe.

After tea the party visited the works of Messrs. Thos. Glenister Ltd., and were conducted by Mr. Hubert Glenister in person, who showed the variety and volume of home-grown timbers used by his firm, including oak, beech, birch, elm (of the Common, Dutch, and Wych varieties). The imported woods used were—Canadian birch, Nigerian walnut, African and Honduras mahogany, from all of which it was noted that fine planks and boards were being obtained, an indication of the care exercised in selection of the timber and its conversion. Air-drying of the stock between skids is principally relied upon with final conditioning for use in heated chambers.

Although employing machinery to a large extent, excellent handicraft work is evident in the production and character of the individual pieces of chairs and furniture, which are finished by highly skilled craftsmen. The examples of chairs, tables, sideboards, and other pieces seen testify to the skill of the operators. An inspection of the finishing sections brought to a close the series of intensely interesting visits which had been arranged for this day. The party then returned to head-quarters at High Wycombe, and were entertained by locally resident members of the Society.

On the morning of Saturday, 3 October, members of the Society paid a visit to the beech woods of the Hampden Estates at the kind invitation of Mr. A. G. Hobart-Hampden, who during the last twenty-five years has spent much time and thought developing the woodlands. The woods are rather more than 1,200 acres in extent and are situated on a fairly level area in the Chiltern Hills, at an altitude of about 700 feet above sea-level. The woods consist principally of beech, with a small proportion of oak and ash.

The party assembled at Mr. Hobart-Hampden's house and entered the woods at a point near by. Before proceeding farther, a brief history of the past management and a description of the present system under which they are worked were given by the leader. In former times selection fellings were made, single trees being felled anywhere within the woods when they arrived at maturity. Little or no attention was paid to regeneration, with the result that very few young trees appeared to take the place of those felled.

It was necessary, therefore, to introduce some system whereby satisfactory regeneration, and, if possible, improvements in the growing stock, could be secured, and in the hope of achieving this end, a working plan was drawn up, under which group selection fellings were substituted for the old method. A rotation of 88 years, divided into four fellings cycles of 22 years, was introduced, and to facilitate working the total area was divided into 11 compartments. In marking trees for felling, groups of mature trees, or of bad trees, or both, are chosen, the areas cleared being a quarter of an acre or more in extent. Weed

growth, chiefly of brambles, springs up in the cleared spaces, and would hamper regeneration very considerably, but when a good supply of seed is observed the weeds are cut down, so that the seeds may have a chance of germinating, and the seedlings of establishing themselves in the following spring. It is interesting to note that under this method of treatment, ash generally comes up readily in the clearings, and it is hoped that later on beech seedlings will be able to establish themselves beneath the ash.

After the system had been in operation for a few years it is apparent that a rotation of 88 years was too short for the production of beech of an exploitable size, so it was extended by another felling cycle to 110 years. The possibility has been fixed at 30,000 cubic feet per annum, equivalent to rather less than 30 cubic feet per acre per annum.

The route through the woods had been so arranged that areas in various stages of regeneration were visited. In some of the areas the ash seemed to have taken complete possession of the ground, while in others beech appeared to predominate. A few seedlings of oak, sycamore, and cherry were also noticed.

In the course of the walk through the woods the party came upon a rude shelter in which a very primitive type of lathe had been set up. On this, chair-legs and staves are turned out from beech clefts, the parts being roughly shaped with a drawing knife before being put into the lathe. The branch wood is first sawn to the requisite lengths and afterwards riven with a wedge and small maul. The finished parts are stacked in the wood to dry, the top of the stack being covered with the chips produced in shaping the legs with the drawing knife, to keep out the rain.

One small plantation of oak was seen, and Mr. Hobart-Hampden explained that this had originally been agricultural land, but the tenancy having terminated, it was sown with acorns. The saplings appeared to be growing quite satisfactorily and compared favourably with young oak crops raised from seed in the Black Forest and other Continental forest regions.

A small plantation of exotic conifers chiefly of Himalayan origin, including such species as *Pinus excelsa* Wallich, *Picea morinda* Link, and *Cedrus deodara* Lawson, was visited, in a wood quite near the starting point. The ride through this plantation was edged on either side with *Cryptomeria japonica* Don. Many of the trees showed satisfactory growth, but it transpired that considerable destruction among the pines and deodars had been caused by the Honey-Fungus, *Armillaria mellea*. It may be worth noting here that the deodar, used as a hedge-plant in Mr. Hobart-Hampden's garden, has produced a fine thick hedge which is regularly clipped, and appears to respond to this treatment very satisfactorily.

It was stated that during the past twenty years the average net annual revenue per acre from the woodlands on this estate has been 3·9 times as great as that from the agricultural land, and it is apparent that the system in operation is not merely securing satisfactory natural regeneration, but also a good class of timber, the boles of the oak and ash as well as the beech being of good length, straight and clean.

Due to the great care and thought with which Mr. Hobart-Hampden had planned the studies for this occasion, and the information he imparted at suitable intervals, this forestry day brought the fourth Annual Excursion of the Society to a close in a manner which it is felt made it a success and pleasure to those who took part in it.

FIFTH ANNUAL GENERAL MEETING

THE Council have decided that the Fifth Annual General Meeting shall be held in Scotland on Saturday, 27 February 1932. As the Annual Meeting and Dinner of the Royal Scottish Forestry Society will be held in Edinburgh on the preceding day, and as the

ERRATUM

Page 163, line 5 from bottom :

for 29th November to the 1st of December
read 29th to 31st December

International Rugby Match, Scotland *v.* Ireland, will be played in Edinburgh on the afternoon of the date fixed, it is probable that the Meeting will be held in Edinburgh on the morning of that day.

The usual notice and copy of the Accounts will be sent to members after the audit has been completed, about the end of January, but members are asked meantime to note that date and try to arrange to attend the Meeting.

RESOLUTION REGARDING TIMBER FROM SOVIET RUSSIA

THE following resolution has been sent to the Prime Minister:

The Council of the Society of Foresters of Great Britain in assembled meeting held at Oxford on the 29th day of May, 1931, debated upon the menace to the future of timber growing in the British Isles, which is foreseen in the flooding of the Home markets with timber from Soviet Russia at prices which are obviously uneconomic from the standpoint of production according to the standard of living obtaining in Britain.

The members of the Council are in constant touch with those who convert and sell home-grown timber and who are gradually losing one market after another through the general depression in prices owing to the marketing of Russian timber on an uneconomic basis.

The Council view with grave concern the effect of the general lowering of timber prices. This will tend to discourage the planting of softwoods in Great Britain, thus reducing the amount of labour required for forest operations and accentuating rural depopulation. It will also reduce the value of existing plantations belonging both to the State and to private individuals.

COMMITTEE ON INTERNATIONAL RELATIONS

The Council recently formed a Committee with the above name, the main functions of which will be to assist forestry visitors to Great Britain by giving them advice and introductions.

The Committee appointed for this year consists of Professor Troup, Imperial Forestry Institute, Oxford, Mr. B. C. Adkin, College of Estate Management, London, and Mr. J. D. Sutherland, Assistant Forestry Commissioner for Scotland at Edinburgh. Any one coming from Overseas, or any member knowing of visitors who might be assisted by the Committee, should communicate with the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh, who will put all visitors in touch with the members of the Committee or others according as may seem best.

THE SOCIETY OF AMERICAN FORESTERS

The Society of American Foresters again very kindly ask any of our members who may be in the United States to be present at and to participate in their Annual Meeting to be held at New Orleans, Louisiana, from the 29th November to the 1st of December 1931.

ANIMAL ECOLOGY

The British Ecological Society propose to found a new journal entitled *The Journal of Animal Ecology*. Those interested can obtain particulars from Mr. Charles Elton, University Museum, Oxford.

REVIEWS

An Outline of Forest Pathology. By Ernest E. Hubert. 543 pp. Chapman & Hall Ltd., London, 1931. Price 30*s*.

Review by W. R. Day.

THIS is the only text-book on Forest Pathology to appear in the U.S.A. since Rankin's *Manual of Plant Diseases* was published in 1918. Books solely devoted to this subject do not appear frequently, and the publication of a new text-book in English raises hopes that something of real service to English-speaking foresters has at last appeared. The author is well known to forest mycologists and pathologists for his work on the decay of timber in North America, and this book is concerned almost entirely with the diseases and problems of forest pathology in North America. Nevertheless, such a book cannot but be of direct interest to foresters in other temperate countries.

The book is divided into three parts. Part I is an introduction, and after a few preliminary pages deals with the classification of tree diseases, the factors influencing disease, the relative importance of tree diseases, economic losses, and symptoms of disease and decay. Part II, headed 'Forest Pathology', deals with various selected individual diseases under the headings of 'non-organic or physiogenic agencies' and organic agencies. This part ends with a short enumeration of control methods. Part III is concerned with 'Wood Pathology'; that is, with the decay of wood in felled and converted timber. It deals respectively with the properties of wood affected by decay, the relative resistance of wood to decay, saprophytic agencies (the wood-decaying fungi), semi-parasitic agencies (wood-staining fungi) and control methods. Part II occupies about three-fifths of the book; the remainder being approximately equally divided between the other two parts.

It is rather difficult to appraise the value of this book. In the first place it is, as its title indicates, an outline of forest pathology; it does not, as a whole, go deeply or thoroughly into the subject, and its standard is elementary rather than advanced. The first page of the introduction indicates that the book is dedicated to the needs of the practising forester, the teacher, the student, and the occasional layman rather than to those of the investigator, but the teacher, who in order to teach should have at least some experience in Forest Pathology, and be to some extent an investigator, will find his needs often neglected for those of the other three. In the second place the book is written to supply the present-day needs of forest pathology in America. It thus stresses certain subjects at the expense of others, only dealing effectively with those which at the moment are of economic importance. Thus at least half the book is concerned with decay-causing fungi, and after that the rust fungi, and fungi such as the chesnut blight (*Endothia parasitica*) receive most effective treatment. Here lies the undoubted value of the book, in that it gives a good outline of the diseases at present of known importance in the forests of North America. This, however, is not exactly the same as saying that it is a good outline of forest pathology even in so far as this subject concerns only one sub-continent.

Many criticisms might be made of details in this book. Part I in particular seemed to the reviewer to be none too well written and difficult to read. In the preface it is stated that 'Neger's work, a German text published in 1919, is the most recent book

treating of tree diseases'. Actually the revised edition of this work in 1924 is the most recent work published before 1930 dealing solely with diseases of forest trees. Similarly, in referring to Sorauer's *Handbuch der Pflanzenkrankheiten* on page 16, reference is given to the first, second, and third editions only; no mention being made of the fourth edition which began to appear in 1921, or of the fifth edition, the first two volumes of which appeared in 1924 and 1928 respectively. These are, however, oversights which any one in touch with a good forest library in Europe will quickly discover.

Occasionally terms do not seem to be quite happily used. Thus, the mistletoe *Phoradendron* is called a 'facultative parasite'. The term 'facultative' implies that the parasitism is optional and is correctly applied to an organization that under the right conditions is able to maintain completely an other than parasitic existence. The mistletoe is, however, compelled to depend on its living host for water supply; and water being an absolute necessity in the economy of a plant, its parasitism cannot in any sense be said to be optional, permissive, or facultative. An example of the inadequate and confusing statement that sometimes occurs may be taken from page 26, from the very short discussion on Heredity and Predisposition: 'It is clear that with certain diseases such as the rusts the primary factor—the causal fungus—is emphasised by the pathogenetist. With other types of diseases, the causal agency is still the primary factor, but secondary factors, such as the conditions influencing the development of the tree, become part of the picture and the predispositionist emphasises these.' This paragraph appears after the bare reference to Hiley's statement in his *Diseases of the Common Larch* on the importance of the vigour of the host as a predisposing factor to needle rusts and larch canker fungus. From this it is presumably supposed to be quite clear to the practising forester, teacher, student, or occasional laymen that the paragraph quoted is true. The paragraph itself seems to imply that in the case of rusts no other factor than the presence of the infecting organism in contact with the host is of importance in the development of disease, which is entirely untrue as a reference to pages 278 and 279 of this book will show. Furthermore, what the 'other types of disease' are never appears to be explained, nor what the 'causal agency which is still the primary factor' may be or what types of thing are the secondary factors which influence it.

These few instances must suffice to show that the book has been written without sufficient consideration. This must not be taken to mean, however, that it does not contain much good work: it does, the chief part being found in the sections dealing with decay of timber. The descriptions of diseases on the whole are sufficient and adequate for a book of this type. Even these are, however, sometimes marred by the tendency to loose or inadequate statement. Thus on page 177 it is stated, regarding *Mycosphaerella laricina* Hartig, that 'In England and Germany the disease has been one of the principal factors in the failure to cultivate the larch'. As regards England this is definitely untrue, and in Germany it is not true without strict qualification. On page 197 *Creonectria ditissima* Tub. is described. In the first place Tulasne and not Tubeuf named this species (which in Europe is usually referred to as *Nectria ditissima* Tul. or *N. Coccinea* (Per.) Fr.). In the second place, the only reference to literature is to Tubeuf's *Diseases of Plants*, published in 1897, a quite useful but not very helpful reference to any student or teacher who found it necessary to read up this disease.

The references to literature are given after each disease or subject dealt with. This is a most convenient practice in some ways, although it means that some references are printed many times and that references are sometimes rather difficult to find when sought for independently of a particular subject. A table of contents is given and also an index. The latter might be improved on at least one point. *Tilia americana* is

given in the index as referred to on page 428 in connexion with brown mottled rot, although nowhere in the description of the rot does this name occur. Presumably one is supposed to know that the common name of this tree is basswood, which name is referred to in the text although not in the index.

The book is well printed and produced. The illustrations consist of photographs and drawings and are on the whole very good.

Unsere Kenntniss von Forstsaatgut. By Prof. Werner Schmidt. 256 pp., large octavo. Fifty-five photographs and diagrams. Der deutsche Forstwirt, Berlin, 1930. Rm. 12.

Review by R. N. Aldrich-Blake

IN this book the director of the forest seed-testing institute at Eberswalde amplifies his own data on the harvesting, kilning, cleaning, storage, and testing of tree seeds by numerous references to continental literature.

He insists that an accurate knowledge of the origin of seed be obtained. For geographical races of trees can be distinguished with certainty neither by their cones nor by their seeds: and seed of two nearly allied species cannot be separated if there are intermediate forms, as in the case of sessile and pedunculate oak. In a review of the literature on seed provenience he stresses the caution which must be taken in accepting phenotypic differences as being truly genotypic.

The seed-testing apparatus in use at Eberswalde is described: and among the results recently obtained therewith the data on seasonal periodicity of germination are presented. Under identical external conditions Scots pine seed germinates much more rapidly in spring than at any other season: but there is no seasonal periodicity in total germination.

The losses resulting from harvesting too early are demonstrated in the second section of the book. Birch seed soon loses its initially low viability if collected early; whereas seed harvested in August may retain a germination capacity of 98 per cent. till the following spring. Scots pine cones picked before November require lengthy kilning, which is both expensive and harmful.

In the third section recent work on the physiology of seeds and seedlings is discussed. It is thought that an extensive study of the reserve materials of seed of geographical races may assist in their distinction one from another. Enzymes are under investigation: and it has been shown that alpine and northern races of Scots pine have a higher catalase activity than lowland and southern races.

The author points out in a short concluding chapter that the provision of seed may be improved through an increase of harvest statistics, and by increased co-operation between seller and buyer.

Seeding and Planting in the Practice of Forestry. James W. Toumey. Second edition, revised and enlarged by Clarence F. Korstian, Chapman & Hall, London, 1931. Price 25*s*.

Review by the Editor

THERE are few forestry books which are so widely known and appreciated by foresters of all grades in this country as Toumey's *Seeding and Planting*. Although written for America, it was rooted in European experience. A new edition has been published, revised, and enlarged by Professor Korstian, who is known for his researches

on subjects bearing on artificial regeneration. This edition follows the first closely in general form and matter. There is an amplification here and there, and some of the results of recent research—principally American—have been added, but the changes are less important than one would have expected, considering that fifteen years have passed since the first edition was published, and much knowledge has been accumulated since that time on the subject of the book. Because such a large proportion of the new matter relates to American conditions, the book on the whole is perhaps less attractive to European foresters than the earlier edition. It is much more definitely an American text-book, but it is confidently recommended to those who do not know the earlier edition, because it covers the subject more completely than any other book in English. The paper, printing, and illustrations are of the high standard one associates with the publishers. A lower standard coupled with a lower price would perhaps have been welcomed by many foresters.

The Grey Squirrel. By A. D. Middleton. Sidgewick & Jackson, Ltd., London, 1931. Price 4*s.* 6*d.*

Review by the Editor

MR. MIDDLETON is already known to readers of *Forestry* for his work on squirrels. This little book of some hundred pages, suitably illustrated, is of a type which interests those who love the countryside. It deserves to be widely known, not only amongst foresters, but all who are interested in Nature. There is nothing dry and formal in the method of presentation. The writing is racy and the view-point thoroughly modern. The life of the grey squirrel is presented in all its intimacies—as far as known—and one of the most interesting portions of the book from the biological standpoint deals with the squirrel fleas. Curiously enough in the Oxford district the grey squirrel has not got its own special flea, but the red squirrel flea, although generally in this country the species associated with it in America is present. A nature story, scientifically accurate, modern, and free from sentimentality is not a common thing, and we feel certain that any one interested in Nature who buys this book will not regret the purchase.

Welsh Timber Trees. H. A. Hyde, The National Museum of Wales and the Press Board of the University of Wales, 1931. Price 1*s.*

Review by the Editor

WE feel certain that this book has only to be known about to be widely purchased. Fortunately the trees, native and introduced, which are dealt with in this book are, in general, the trees of the British Isles as a whole, hence we can all profit by the enterprise which has resulted in this publication.

The book is so arranged as to appeal to all. There is an introduction which explains botanical terms and classification, and gives a general account of Welsh vegetation. Thereafter each tree is described in detail: flowers, fruit, growth and notable trees, and timber. There are numerous illustrations of flowers, leaves, &c., and also stands and individual trees. In general these illustrations reach a high standard.

The low price of issue brings the book within reach of all, and cannot but increase the interest in all sections of the public in trees and forestry. The Natural Museum of Wales is to be congratulated in its enterprise, and Mr. Hyde in the execution of the work.

Forest Gardens: Forestry Commission Bulletin No. 12. H.M. Stationery Office, Adastral House, Kingsway, London W.C.2. Price 2*s*. 6*d*. net.

Review by Thomas Thomson

A FOREST garden is an experimental area in which different species of forest trees are grown under silvicultural conditions in order to test their behaviour. This bulletin gives a description of five such forest gardens in different parts of England and Wales. The gardens in question are situated in Cockle Park, Northumberland; at Cirencester; in the Forest of Dean; in Alice Holt Woods, Hants; and at Ceiriog, Denbighshire.

The first part of the bulletin contains a description of the locality of each forest garden and a detailed description of the plots. The figures given for height and diameter growth and the comments made on the form, health, and appearance of the species, and their behaviour in pure crops and in the various mixtures, will form a useful guide to the selection and treatment of species for sites with climatic and topographical conditions similar to those of the gardens. One of the main functions of forest gardens is to test out, under similar conditions of soil, climate, and exposure, the merits of different species, and methods of treatment. At the time when these particular areas were planted, this was probably the main object of those responsible for founding them. Uncommon species and mixtures were introduced experimentally on a small scale as well as the already well tried.

The second part of the bulletin discusses the rates of growth of the species in each forest garden. The course of height growth of each species in the various plots is worked out from stem analyses and the records of past measurements. The figures thus obtained together with the climatic and topographical data are used in the last part of the bulletin as a basis for the discussion of the rates of growth of each species in relation to the factors of the locality. In this connexion it is pointed out that the distribution of the gardens in England is irregular, in that three out of five are in the west and south-west whilst of the others one is in the south and the other in the extreme north-east. None of the areas is in a district of high rainfall. As regards elevation four of the gardens are situated below the 500 feet level, whilst the Ceiriog area lies between 1,000 and 1,250 feet and is between 600 and 700 feet above the level of the valley below. It is moreover much more fully exposed than the other areas. In view of the fact that most of the species employed in the gardens are conifers, it is perhaps unfortunate that, with the exception of Ceiriog, none of the areas is on a typical site for conifers.

These circumstances limit the scope for generalization from the results, but nevertheless some very interesting comparisons are made and deductions drawn as to the effect of the site factors on the growth of different species. Among the points noted are the effect of exposure on the height growth of European larch, the maintenance of rapid height growth by the Japanese larch at the high elevation of the Ceiriog area on light loam and its comparative failure on heavy soils, and the fact that none of the gardens provides conditions for the best growth of Douglas fir, the more sheltered areas having too heavy soils, and the elevation and exposure of the Ceiriog area outweighing the advantage of its light loamy soil.

The bulletin contains a number of height-growth curves and photographs of interesting plots, and forms a valuable record of the condition of the gardens when they have just entered upon the thinning stage. With the exception of Cockle Park, which was planted in 1898 and 1899, none of the plots are more than 27 years old at the present time, and the final results are still matters for the future.

Valuable features of the bulletin are the plans of the areas and maps showing their situation so that a visitor, armed with the book, will have a useful guide which not only gives recent statistics but also an account of the origin and past treatment of the plots.

The Effect of Progressive Decay by Trametes serialis Fr. on the Mechanical Strength of the Wood of Sitka Spruce. By K. St. G. Cartwright, W. P. K. Findlay, C. J. Chaplin and W. G. Campbell. Bulletin No. 11, Forest Products Research Laboratory.

Review by W. R. Day

THE importance of the protection of timber from fungi attack, when it is said to be used for purposes in which mechanical strength is important, will never be fully realized until it is known in what manner and how rapidly fungi are able to affect the strength of the timber concerned. The chief importance of this paper probably lies in its being a very definite and excellent contribution to our knowledge of this as yet but very little investigated subject. The investigation is concerned with a fungus which has already been described in a Forest Products Research Bulletin (No 4) and which is of interest in that it colonizes the timber, Sitka spruce, after felling. It is therefore an organism, the attacks of which are to be controlled by rapid extraction and careful handling of the timber on the way to conversion.

In this investigation small pieces of wood 8 inches square in cross section and 5 inches long were placed in a flask in which a pure culture of the fungus was growing. They were taken out after periods varying from one to ten weeks and their mechanical strength tested by a static bending test. Also, in order to estimate the relative advance of decay, the alkali solubility of the tested pieces was determined. The experiments showed that after only two weeks over 15 per cent. loss in mechanical strength had occurred. The loss in strength continued to be rapid and at a fairly constant rate until a loss of 80 per cent. of the original strength values of the timber had been reached. Increase in alkali solubility was apparent from the beginning and could be closely correlated with loss in mechanical strength. Loss in weight was not appreciable at first, and was preceded by an increase in alkali solubility, thus, showing that decomposition precedes appreciable loss in weight and indicating that the loss in strength is due rather to the chemical action on the cell wall than to its physical breaking down by hyphal penetration.

To the practical man the rapidity with which this fungus is able to reduce the strength of the timber is the point of immediate importance, and undoubtedly it calls for such organization in the extraction and conversion of this timber, that no time is given for the wood to become penetrated by the fungus. The urgent necessity for such organization is, however, only to be realized from the results of such work as this.

NOTICES

The Training of Candidates and Probationers for Appointment as Forest Officers in the Government Service. H.M. Stationery Office, Price 1*s*.

IN May 1930 the Secretary of State for the Colonies appointed a committee consisting of Sir James Irvine (*Chairman*), Mr. G. E. S. Cubitt, Major R. O. Furse, Sir Thomas Middleton, Sir Roy Lister Robinson, Mr. F. W. H. Smith, and Mr. C. G. Trevor 'To consider and report on the training of candidates and probationers for appointment

as forest officers in the Government Service'. In October 1930, Mr. Trevor resigned from the committee, and Sir Alexander Rodger was appointed in his place.

The following is the Committee's summary of their conclusions and recommendations:—

(1) When the requirements of the Services are taken into considerations the courses of instruction in forestry now given in the Universities are not satisfactory, particularly in respect of field work.

(2) A forest officer cannot be adequately trained in a course restricted to three years.

(3) The cost of extending the forestry courses to four years in all the Universities concerned and of bringing each course up to the required standard would be prohibitive.

(4) The Services offer the main opportunities for the employment of graduates in forestry, but each year only 20 to 25 probationers are required. This demand is unlikely to be exceeded in the near future.

(5) For the requirements of the Services it is unnecessary to have as many as five Schools of Forestry, and the provision of additional State aid in support of these Schools cannot be justified under existing conditions.

(6) The standard attained by the candidates who present themselves for appointment to the Services affords evidence that recruitment is on too narrow a basis.

(7) We recommend that in future the course of training should extend over four years, of which the first three only should be taken at one of the University Schools of Forestry, the final year being spent at the Imperial Forestry Institute.

(8) The University degree courses should be remodelled so as to concentrate the training on the fundamental aspects of forestry, as exemplified by European practice, omitting the more highly specialized branches of the subject.

(9) The Imperial Forestry Institute should be made responsible for instruction in the specialized subjects named in our Report, and should become a permanent and essential feature of the pre-Service training of forest officers.

(10) Provision should be made to facilitate the recruitment of candidates who have read for Honours in Arts or Science. This can best be secured by the institution of a scholarship scheme, the conditions of which should be kept as elastic as possible.

(11) We recommend that any University which desires to present candidates for the Forest Services should be required to maintain its instruction at a satisfactory level of efficiency, and we suggest the means by which this can be secured.

Imperial Bureau of Soil Science Publications.

THERE is now no lack of realization by foresters of the importance of soil science in their profession. They are painfully aware, however, of the lack of knowledge on which to base practical silviculture. To date, research in soil science has been directed to agricultural soils. This is quite what one would expect, but it is now being realized to some extent, that soils will never be fully understood unless attention is directed to natural, that is undisturbed, soils. It is this latter category which is important in forestry, whether one is dealing with natural or artificial regeneration, hence although research directed mainly from the agricultural standpoint can never solve our forest soil problems, such research may be expected to impinge more and more on aspects of interest or importance to forestry. The attention of readers is drawn, therefore, to selected publications of the Imperial Bureau of Soil Science.

Technical Communications Nos. 5 and 16. Soil Erosion. This is a subject of great importance in many countries. These publications summarize both published work and statements of investigations on progress. Extensive bibliographies are given. Members may be able to supply further information to the bureau on this subject.

Technical Communication No. 6. The American Method of Soil Classification and Survey. By Dr. Linwood L. Lee. Soil classification is a subject of vital importance in forestry. The methods described have been elaborated as the result of thirty years' work in the United States of America. It is not considered that this system is the most suitable for the classification of forest or potentially forest soils, because the emphasis is very strongly on texture which, except at the extremes, is of less importance in forest soils than the humus horizon and general development. The method, nevertheless, merits careful consideration.

Technical Communication No. 7. Methods of taking Soil Profiles. This communication deals with methods of taking soil profiles for purposes of permanent record. The methods of Polynov, Miklaszewski, Schlacht, and Prescott are described. Foresters are probably more aware than soil scientists of the interest and variety of the natural soil types of Great Britain, and could assist appreciably in building up a representative collection of profiles. This contribution is, therefore, of interest to us.

Technical Communication No. 9. The Colorimetric Determination of Phosphoric Acid in Soils. Recent research has confirmed that trees, particularly conifers, are very sensitive to phosphoric acid. Whether this is directly nutritional or some indirect effect on the metabolism of the associated mycorrhiza remains to be demonstrated, but the methods here described will undoubtedly be useful when forest soil science develops.

Technical Communication No. 17. Proceedings of a Conference on Soil Science Problems Sept. 16–18, 1930. Some of the subjects dealt with were: The present position of soil analysis, soil surveys, and methods of field experimentation.

Technical Communication No. 19. Air Survey in Relation to Soil Survey. By Ray Bourne. Where large areas have to be surveyed rapidly, and there are no topographical maps, air soil survey will almost certainly prove a valuable method. It is not impossible also that it will yet prove useful, at least for preliminary surveys, where more extensive methods are necessary.

Types of Humus Layer in the Forests of North-eastern United States. By L. G. Romell and S. O. Heiberg. *Ecology*, xii. 567–608, 1931.

THE paper represents a first systematic effort of applying outside Europe the principles and method laid down by P. E. Müller in his classical studies on natural types of humus layer. It is also a contribution to the question of classification and nomenclature of forest humus layers in general. After a critical review of the different proposals of classification, the authors conclude that Müller's system fits the natural conditions best. That this holds true for American conditions as well is indicated especially by the flora characteristic of different types of humus layer. A fundamental point of Müller's system is that the classification applies to the entire humus layer (i.e. the top layer of the soil, owing its characteristic features largely to its humus content; no matter whether this content is high or low and whether the humus is 'incorporated' or not). The authors strongly oppose the tendency inaugurated by Ramann to classify the humus alone, which is only one constituent of the biological unit. Müller's two main types or groups are retained.

The distribution of the types within the region is discussed. Groundwater conditions seem to be a particularly important factor locally. Some plants are listed as indicators

of mull and of duff. The most valuable hardwood species of the region seem to be among the mull preferring plants.

Data are presented on nitrification, pH and lime content of the different types. Contrary to European experience, nitrification was found in the laboratory within all types, even pronounced duffs, and down to a pH of 2·9 which was close to the lowest pH value encountered in any sample, whether nitrifying or not.

The main data are given in concentrated table form on eight pages. A mimeographed Appendix of 29 pages, distributed by the authors, gives descriptions of seventeen chosen localities including vegetation and soil notes, Bouyoucos analyses, &c. L. G. Romell.

Empire Forestry Handbook, 1931.

A REVISED edition of this exceedingly useful handbook, edited by Mr. Fraser Story, has been issued, and all interested in forestry should possess a copy. The principal sections deal with the Empire Forestry Association, Forest Officers of the Empire, Higher Forestry Education, Research Institutes, Departments and Institutions dealing with Imperial Forestry, Forest Resources of the Empire, Arrangements for the investigation of Empire timbers, and trade names of Empire timbers.